A PARTIAL REPORT

ON

THE GEOLOGY OF WESTERN TEXAS

CONSISTING OF

A GENERAL GEOLOGICAL REPORT

AND

A Journal of Geological Observations along the Routes Traveled by the Expedition between Indianola, Texas, and the Valley of the Mimbres, New Mexico, during the Years 1855 and 1856; with an Appendix giving a Detailed Report on the Geology of Grayson County.

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INTRODUCTION.

The papers here given to the public consist, first, of "A Journal of Geological Observations along the routes traveled by the Expedition between Indianola, on the Gulf of Mexico, and the Valley of the Mimbres, New Mexico," in 1855 and '56; secondly, "A General Geological Report" thereon; and, thirdly, an Appendix embodying a detailed report on the Geology of Grayson County. They are from the hitherto unpublished manuscripts of Prof. George G. Shumard, who was Assistant State Geologist at that time to Prof. B. F. Shumard, the Chief of the Geological Survey which had been authorized and ordered by the State, but which was never completed in consequence of the breaking out of the war between the States.

These papers were probably intended as notes, or rather as the basis for more careful and elaborate official reports to the Chief Executive of the State, and the Legislature. Although they cover comparatively a very small portion of our Imperial State, they contain a great deal of scientific and what may be called "field note" information of the highest practical importance, not only to Western Texas, the Prairies and the Great Plains, to which they chiefly refer, but also to the entire State. No friend of Texas can read these somewhat crude but sensible documents without experiencing a feeling of deep regret that they were not officially printed and published to the world when first prepared, for it is apparent that the facts and information, scientific and practical, that they so clearly bring to view, would have been of inestimable service to a generation then in its prime, but now passing away; the knowledge contained in them would have then led to a development of both the mineral and agricultural wealth of the State, which has been retarded for years. For example, on the second page of the accompanying "General Geological Report" on Western Texas, the reader encounters the following brief but expressive paragraph:

"*Many of the soils encountered upon the Plains are found to possess*

in an eminent degree all the necessary elements of nutrition for plants; and if this region were accompanied with the requisite meteorological conditions, it would possess a character for fertility unsurpassed by any portion of the North American Continent."

Now, how are these indispensable "meteorological conditions" to be obtained? The progress and developments made on both sides of the Atlantic during the past and present century, in the science of Forestry in connection with Meteorology, have shown that there is but one very plain and easy way, and that is by covering one-fourth to one-third of the Plains' surface with forests. Every section of 640 acres on the Plains and Prairies of Texas should have upon it from 150 to 200 acres of well-timbered woodland. Procure the seed or scions of the right kinds of growths, suited to the soil and climate, such as Catalpa *speciosa* (the most durable of all known growths and best suited for railroad cross-ties), China Aster, Hickory, Maple, Black Locust, Walnut, Chestnut; White, Post, and Live Oak; Ash, Bois d'Arc, etc., etc., and respectable forests could be grown in 30 years or less time; and enough of the same from the necessary thinning out, beginning the fourth or fifth year, could be sold in the meantime to pay all expenses. Experience in Germany and other parts of Europe proves this, and it proves, too, that by or before the end of 30 years the desired "meteorological conditions" may become such all over the Plains and Prairie country and adjacent regions, that destructive summer drouths and devastating freshets would be reduced to the *minimum;* countless perennial fountains would bubble up from the generous bosom of Mother Earth, and all of these streams great and small would run reasonably full the year round; and much of the Texas prairie country, the "black hog-wallow lands," for example, already productive enough, even under present "drouthy" conditions, to make them equal the best lands in Eastern States, would, with the increased and equalized rainfall sure to follow foresting and re-foresting, become unsurpassed in fertility.

Of course, farmers on the Plains or Prairies of the West, or those having lands there that they may wish to colonize, ought to begin by boring Artesian wells for immediate purposes. These would also assist materially in bringing about the desired change in meteoro-

logical conditions; in restoring and equalizing the rainfall; and, in the meantime, judging by what has happened in some other States, might be utilized, to some extent, for irrigating purposes.

Unquestionably, much of the future greatness of Texas will depend upon the success of her people, in producing, by comprehensive management and concerted action, "the requisite meteorological conditions" referred to by Prof. G. G. Shumard, over all that region of the State lying West of the 98th Meridian of West longitude. Produce those conditions over all that immense territory of prairie and plain, lake, river, and mountain, stretching from Austin, Palo Pinto, and Wichita to the Rio Grande, and, as a matter of course, it will have a healthy and beneficial effect on every other part of the State.

In consideration of the importance of the subject to the whole people of Texas, I take the liberty of publishing an Abstract of a Geological Report made by Prof. B. F. Shumard, State Geologist, and by him submitted to the Legislature at its Eighth Session. This Abstract gives a brief, but very comprehensive and compendious statement of the progress of the Geological Survey of the State up to August 1st, 1860. It embodies a great many important facts in reference to the agricultural and mineral wealth of Texas—especially the latter—which are as yet but little known to the public at large. When it is remembered that this Report was never officially published by the State, or if it was, that like the journals and other documents of the Legislature to which it was submitted, were burned in the fire which destroyed the Capitol, thus leaving no copy extant—nothing, except this Abstract which is copied from the "Texas Almanac" for 1861—it will be admitted that it is in the line of the public good to reprint it now. (See Appendix.)

In the Abstract of Prof. Shumard's Report, it will be seen that as early as 1860 he, as State Geologist, had ascertained that in addition to incalculable quantities of Lignite, Texas also possessed enough Coal of superior quality to supply the demands of her people for centuries to come. Further, it may be stated, that a lack of information as to the existence of valuable and even immense deposits of such Minerals as Copper, Lead, Silver, etc., widely pre-

vails, which are clearly if not fully reported upon in the accompanying papers.

Dr. George Gettz Shumard, whose geological survey of a portion of the State of Texas is now for the first time published, was a graduate of the Medical School of Louisville, where he combined the study of Geology with that of Medicine.

In the year 1850 a Military Expedition was organized by the War Department to explore the sources of the Red River of Louisiana. Captain R. B. Marcy was appointed to command, with Capt. G. B. McClellan as assistant, and the following year another Expedition was organized to explore the sources of the Brazos and the Big Wichita Rivers of Texas. In both of these Expeditions Dr. Shumard served in the double capacity of Surgeon and Geologist. One of the most important objects of these Expeditions was to gain a better knowledge of the geology of the country adjacent to these rivers, and the selection of Dr. Shumard as Geologist was a high recognition of his eminent ability.

On the termination of the surveys, complete and exhaustive reports showing the results of the Expeditions were made by the General Government.

In March, 1852, another Expedition was ordered by the War Department, "To make an examination of the Red River of Louisiana, and the country bordering upon it." This was also under command of Capt. R. B. Marcy and Geo. B. McClellan, Dr. Shumard again accompanying them as Geologist, Paleontologist, as well as Surgeon of the Expedition. In 1853 a report of this survey was published by the War Department. A large collection of fossils and other specimens, collected by Dr. Shumard on this Expedition, were forwarded, with his notes, to Edward Hitchcock, then president of Amherst College, for his examination, and the result was a joint report published in 1853 of "The Expedition of 1852," a work comprising several volumes.

In the year 1855, Dr. Shumard was appointed Geologist and Surgeon to the Expedition ordered by the War Department, under command of Capt. John Pope, of the Corps of Topographical Engineers of the United States Army, who was directed to explore a

large portion of the plains of Texas and New Mexico, with the purpose of testing "in those distant regions the practicability of obtaining water by means of Artesian wells."

To ascertain the practicability of building the Southern Pacific Rail Road was also an especial object of this Expedition.

Dr. Shumard was engaged in this work about three years, when in 1858 his brother, Dr. B. F. Shumard, President of the Academy of Science, St. Louis, was appointed State Geologist of Texas, and he Assistant Geologist.

The surveys for which the above appointments were made were carried on with vigor for more than two years, until the war between the States coming on they were discontinued, and Dr. Shumard left the State, arriving at Cincinnati, Ohio, on the 5th of April, 1861, and on the 8th of the same month was appointed Surgeon General of the State of Ohio.

During his connection with the Geological Department of Texas Dr. Shumard, from time to time, made various reports which are well known. Scientists will remember his discovery of an American substitute for gum arabic.

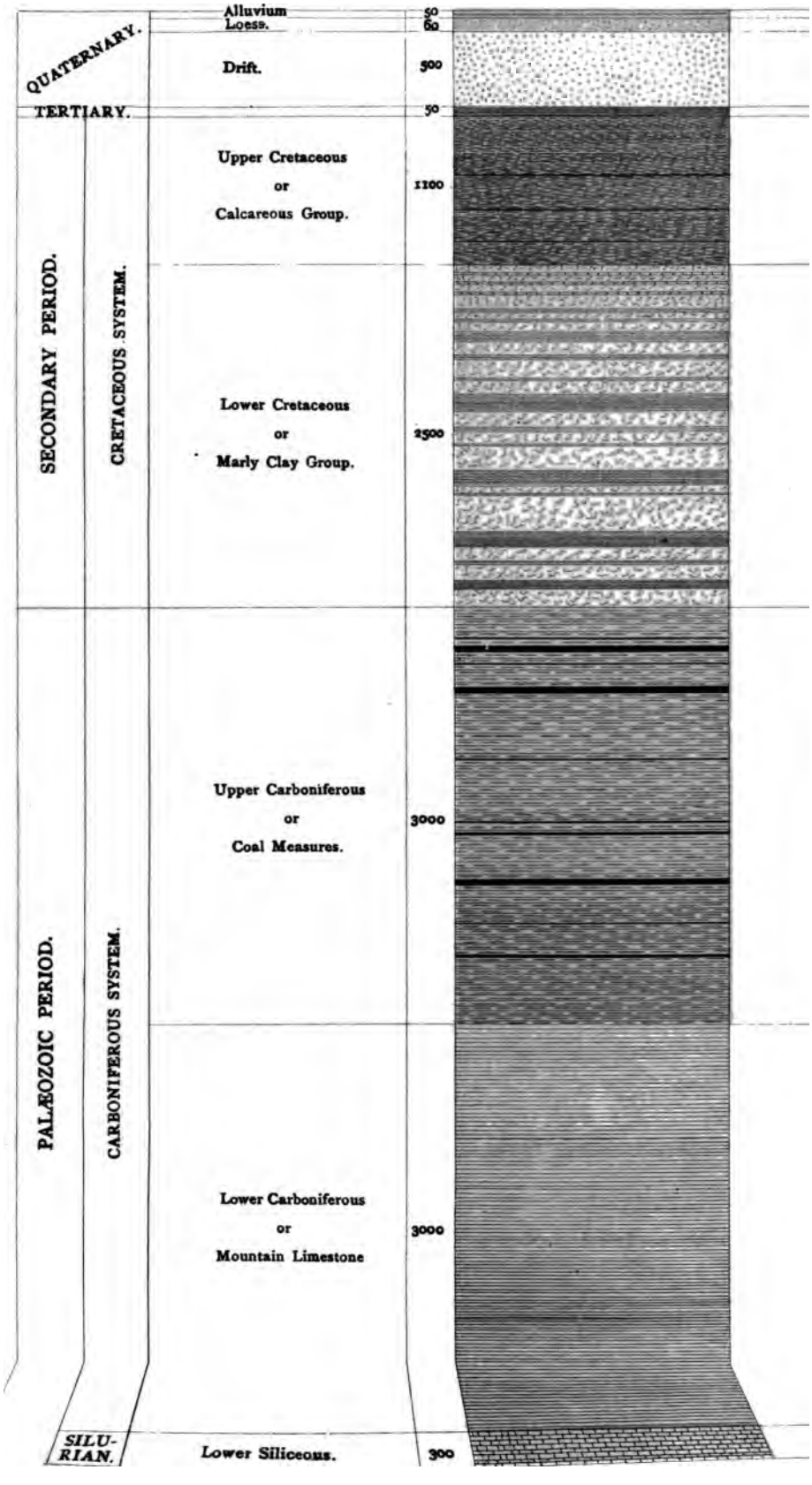
Dr. Shumard's public career, as a geologist, closed with his leaving Texas. He, however, in private, continued his studies, and contributed largely, by correspondence, to various scientific societies, of which the following are the most prominent: The Geological Society of London and of France, the Imperial Geological Society of Vienna, the Geological Society of Hermstadt, and the Academies of Science of Philadelphia, California, Cincinnati, New Orleans, and others of repute.

H. P. BEE,
Commissioner of Insurance, Statistics, and History.

AUSTIN, *August* 20, 1886.

ERRATA.

Frontispiece, third column, for "Lower Siliceous," read *Lower Silurian.*
Page 13, first line, for "*subforsiformis,*" read *subfusiformis.*
Page 13, tenth line, for "*lævinscula,*" read *læviuscula.*
Page 13, fourteenth line, for "*æpuoreus*" read *æquoreus.*
Page 22, last line, for "unheaved," read *upheaved.*
Page 28, twenty-seventh line, for "*Hemitile,*" read *Hematite.*
Page 28, third line from bottom, for "tatiniferous," read *titaniferous.*


QUATERNARY.
Alluvium
50
Loess.
60
Drift.
300
TERTIARY.
50
SECONDARY PERIOD.
CRETACEOUS SYSTEM.
Upper Cretaceous
or
Calcareous Group.
1100
Lower Cretaceous
or
Marly Clay Group.
2500
PALÆOZOIC PERIOD.
CARBONIFEROUS SYSTEM.
Upper Carboniferous
or
Coal Measures.
3000
Lower Carboniferous
or
Mountain Limestone
3000
SILU-
RIAN.
Lower Siliceous.
300

PART FIRST.

GENERAL GEOLOGICAL REPORT.

BY GEO. G. SHUMARD.

CHAPTER I.

The region of country the geology of which forms the subject of the present report lays to the west and southwest of the State of Arkansas, and is comprised principally within the limits of the 29th and 35th degrees of latitude and the 94th and 108th degrees of longitude. It extends, on the one hand, from a line drawn from Indianola, on the Gulf of Mexico, by way of San Antonio de Bexar, Fort Inge, and Fort Clark, to Fort Davis, north to within a short distance of the Canadian River; and, on the other hand, from the western borders of the State of Arkansas and the district immediately south as far west as the Mimbres Mountains, situated sixty miles west of the Rio Grande.

Confined as my observations have been merely to detached portions of the region here indicated, and often compelled to conduct examinations hastily, I cannot hope to do more than present a general outline of its leading geological features. I shall, however, avail myself freely of notes taken during my former expeditions to the sources of the Brazos, Big and Little Wichita, and Red Rivers, and also refer to the observations of such other explorers as have had opportunities of visiting portions of the same field that I have not been able to examine myself.

The accompanying vertical section [*Frontispiece*] is intended to represent approximately the general character, thickness, and relative order of the different stratified formations encountered by myself in the district under consideration. It has been compiled from more than two hundred local sections taken in the course of my explorations in the Expedition under your charge and during former expeditions under Capt. R. B. Marcy. I trust it will be found as correct as could be expected from the necessarily rapid manner in which many of the examinations were conducted.

The first and second columns of the section contain the numbers and names of the several *Geological Systems;* the third, the subdivisions of the *Systems* into *Formations;* the fourth, their estimated *thickness;* the fifth, the *colors* employed to represent them; and the sixth, their *general lithological* character.

It will be seen that all the stratified rocks of this region may be referred to five of the principal systems of geologists, as follows: Quaternary, Tertiary, Cretaceous, Carboniferous, and Lower Silurian. *Each* of these will now be described separately

QUATERNARY DEPOSITS.

The Quaternary System comprises all the deposits of later date than the Tertiary, and in descending order includes: 1st, *Alluvium;* 2d, *Bluff Formation* or *Loess;* and, 3d, *Drift* or *Boulder Formation.* Their aggregate thickness in the district under consideration has been estimated approximately at about six hundred feet.

ALLUVIUM.

This formation comprises: 1st, *Soils;* 2d, *Sand* and *Pebbles;* 3d, *Clays;* 4th, *Stalactites;* and, 5th, *Calcareous Tufa.*

SOILS.

When we consider the extent of surface and variable geological composition of this district, it is not surprising that we should find within its limits a great variety of soils. These, it is well known, derive their character mainly from the mineralogical composition of the underlying strata; and in proportion as these abound in materials favorable or unfavorable for the nutrition of plants, will the soil, other things being equal, be productive or unproductive.

Many of the soils encountered upon the Plains are found to possess in an eminent degree all the necessary elements of nutrition for plants, and if this region were accompanied with the requisite meteorological conditions it would possess a character for fertility unsurpassed by any portion of the North American continent.

Marly Clay Soil.—The most extensive and under favoring circumstances the most productive variety of soil is that derived from the Marly Clay Formation, which is spread over thousands of square miles of surface. It is for the most part of a deep red or brown color, and contains silica, carbonate and sulphate of lime, allumina, magnesia, and oxide of iron, in variable proportions. Could any means be adopted for transporting it to market it would be highly valuable as a manure. Along the streams and in other moist situations it is generally thickly covered with vegetation.

Gypsum Soils.—Gypsum enters largely into the composition of many of the soils of the Plains, and often in such quantities as to constitute their most abundant ingredient. These soils are sometimes white, but more frequently of a light grey, bluish, or red color. They are usually very light,

and may generally be easily recognized, even at a distance, by the deeper color of the grass growing upon them. These soils are also remarkably well adapted as fertilizers, for which purpose they will doubtless hereafter be extensively employed.

Calcareous Soils.—The soils overlying the limestone of the Upper Cretaceous group usually contain a very large proportion of carbonate of lime, which, indeed, is sometimes present to such a degree as to render the land entirely unproductive. When mixed, however, as is usually the case, with a fair proportion of other ingredients, a highly productive marl is formed.

Soils of the Paleozoic Period.— Although generally less favorably constituted than any of the preceding, many of the soils derived from the decomposition of the Paleozoic rocks are, owing to the more favorable meteorological conditions of the regions in which they occur, far more productive. These do not present a great deal of difference in general mineralogical composition, but vary considerably in the amount of vegetable matter they contain. They consist chiefly of lime and silica in different proportions, with an admixture of alumina, iron, and vegetable matter.

Soils of Igneous Rocks.—Few of the soils derived directly from the igneous rocks have been found of much value. They are generally loose, of a deep red or brown color, and are composed mainly of quartz and felspar in coarse and fine particles. When they contain small quantities of clay, lime, or gypsum, as is sometimes the case along the streams, they become highly productive and are clothed with rich vegetation.

PEBBLES.

Water-worn pebbles are of frequent occurrence in the beds of the different streams of Texas and New Mexico. They are derived mainly from the Boulder Formation and older rocks, and exhibit almost every variety of composition. In the beds of the Upper Brazos, Big Witchita, and Red Rivers, they are sometimes accumulated to the depth of four or five feet.

Various metallic ores, as copper, iron, and manganese, have been found in connection with these deposits. In Otter Creek, a small affluent of Red River, having its source in the Witchita Mountains, two small specimens of bluish-yellow quartz, containing gold in small quantities, were found.

SAND.

To the Alluvial Period we must refer those accumulations of loose sand which occur in the beds of nearly all the streams of Texas, New Mexico, and the adjacent Indian Territories, and which are also occasionally met with in situations remote from existing water-courses. The latter sometimes cover many square miles of surface, and appear to be continually shifting their position. Examples of these shifting sands are to be met with near

the headwaters of Red River, in the "Sand Hills" of the Llano Estacado, and immediately west of the southern extremity of the Guadalupe Mountains.

In the beds of the larger streams of Texas, accumulations of sand occur many feet in thickness. These often absorb a large quantity of water; and hence it not unfrequently happens, particularly near the sources of these water-courses, that while the beds appear perfectly dry at the surface, by digging down a few feet plentiful supplies of water may be obtained.

CLAYS.

Clays, derived principally from the destruction of the cretaceous strata, are frequently met with along many of the streams. They are usually of a deep red color, and contain lime and gypsum in variable proportions. Many of the principal rivers of Texas, as the Canadian, Red, Colorado, Witchita, Brazos, and Pecos, either have their sources in or flow for a part of their course through the marly clays of the Cretaceous System. These clays mingling with the water impart to the streams their highly characteristic red hue, and are thus transported hundreds of miles. During freshets these materials are deposited in the form of fine sediment upon the adjacent lowlands, and to this circumstance is due the surprising fertility of many of the valleys bordering the lower portions of the streams of Texas.

STALACTITES AND STALAGMITES

Are abundant in various portions of Texas and the adjacent Territories In the caverns of the Sacramento Mountains specimens of rare beauty occur. They are generally composed of carbonate of lime, and most frequently occur in districts where the Paleozoic rocks prevail.

CALCAREOUS TUFA.

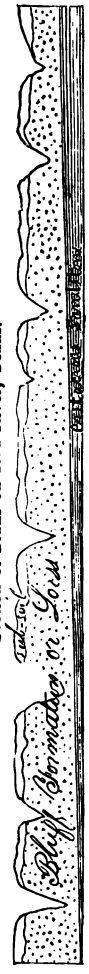
In a single locality, viz., in the vicinity of San Antonio, Texas, I have found a deposit of calcareous tufa. It is here light, porous, and chalky, and contains impressions of leaves and stems of recent plants. The rock is sufficiently firm to be employed as a building stone.

BLUFF OR LOESS FORMATION.

The formation to which the term "Bluff" has been applied by Prof. Swallow, State Geologist of Missouri, and which, in the United States, is usually regarded as the equivalent of the Loess of the Rhine, we have recognized at a number of localities in Texas. As in the State of Missouri and other portions of the West, it is here found reposing upon the Boulder

Formation, and usually consists of thick beds of indurated ash colored loam, containing more or less calcareous matter and abounding in existing species of terrestial and fluviatile shells.

Near Preston, on Red River, a good section of this formation is exposed in a range of vertical bluffs, which extend up and down the river for the distance of several miles. It is here seen resting directly upon soft bluish sandstone of the Cretaceous Period. Fossils are very abundant in this locality, and usually they are in a good state of preservation. They belong chiefly to the genera *Lymnea*, *Physa*, *Planorbis*, *Pupa*, *Helix*, and *Helicina*, and many of the species are identical with those occurring in the loam of New Harmony, Indiana, and elsewhere in the Mississippi Valley, which Sir Charles Lyell, during his visit to the United States, regarded as being the equivalent of the Loess of the Rhine.



No. II. Section of Bluffs on Red River, Texas.

The following is a section [No. II.] of the Loess Bluffs near Preston, on Red River. The entire thickness of the formation in this vicinity is about twenty-five feet.

Sixty miles west of Preston, on a small stream known as the Elm Fork of Trinity River, the Bluff Formation is also exposed. It here reposes upon coarse drift, which rests upon Cretaceous Limestone. Its thickness as exhibited here is about thirty feet. It is occasionally highly discolored with oxide of iron, but otherwise does not differ lithologically from that on Red River, and it abounds in the same fossils. Seventy miles farther southwest, on another small branch of Trinity River, is a formation agreeing in lithological appearance with the Bluff, presenting a thickness of more than sixty feet. No fossils, however, were detected in this deposit.

On Loess Creek, a small tributary of the North Branch of Red River, this formation is again well exposed. It here exhibits a thickness of from thirty to forty feet, and is crowded with fossils of the same species of terrestial and fluviatile shells as characterize the formation farther east.

Although there are deposits which very closely resemble the Bluff Formation at several points along the route from Indianola to El Paso, I have not as yet been able to recognize it with certainty south of the 33d parallel of latitude.

On the Rio Frio and Nueces sections of indurated calcareous loam, sixty to seventy feet thick, are exposed, resting on a deposit of water-worn fragments of hard limestone. (*Vide Journal.*) We are inclined to refer this loam to the age of the Bluff, and should this opinion be found correct, it would give to this formation a geographical range in Texas of not less than four hundred miles.

DRIFT OR BOULDER FORMATION.

During my journey to the sources of Red River, in company with Capt. R. B. Marcy's Expedition, heavy deposits of loose materials, consisting of quartz, greenstone, granite, porphyry, and water-worn shells of the Cretaceous Group, were frequently encountered, resting upon the stratified rocks of the Secondary Period. As the materials forming these deposits were totally different from the rocks occurring *in situ* anywhere in the neighborhood, and apparently had been transported from a distance, we ventured in our notes on the general geology of that region to refer them to the age of the Drift or Boulder Formation.* Since then we have examined deposits of a similar character in other parts of Texas, and have not only had that opinion fully confirmed, but have succeeded in tracing them south and west over a very large district of country.

The Boulder Formation of the region we are noticing varies considerably in character and thickness. In some places it is composed almost entirely of pebbles and small boulders of eruptive and metamorphic rocks, while in others it consists altogether of angular or rounded fragments of Paleozoic and Cretaceous rocks. In Southern Texas it is almost exclusively made up of limestone, sandstone, and silicious nodules, but as we travel north the deposit consists mainly of eruptive and metamorphic rocks. The formation in various parts of the district is often cemented into a conglomerate by means of calcareous or ferruginous matter. As a general rule it is much thicker and coarser as we travel westward. In Western Texas and New Mexico it sometimes attains a thickness of several hundred feet, and contains blocks of sedimentary and eruptive rocks two or three feet in diameter.

Near the headwaters of Red River the Boulder Formation occurs in gently rounded hills from a hundred to a hundred and fifty feet in height. It is here composed of well-rounded pebbles and small boulders of igneous and metamorphic rocks, with occasional beds of coarse silicious sand interstratified, and often contains water-worn fossil shells of the Cretaceous Era, and fragments of silicified monocotyledonous and dicotyledonous wood, weighing occasionally several hundred pounds. Specimens of this fossil wood were submitted to Prof. Hitchcock, who pronounces it to be analogous to that obtained from the Tertiary Deposits of Antigua and the desert near Cairo in Egypt.*

This formation may be also traced from near the sources of Red River, almost continuously, but greatly diminished in thickness, as far east as the mouth of Cache Creek, and even east of that point. Farther south, on the Big Witchita and Upper Brazos Rivers, it is again met with, but here is constituted mainly of water-worn fragments of Cretaceous Limestone, re-

* Red River of Louisiana, by Capt. R. B. Marcy.

plete with characteristic fossils of that formation, and for the most part firmly cemented with a calcareous paste. Its average thickness here we have estimated at about fifty feet.

In Eastern Texas, Dr. F. Roemer encountered thick beds of loose sand and silex, which he refers to the Diluvial Period. These, he states, form a broad belt of "bad land," extending from north to south across a very considerable portion of the State.

This belt was crossed by the Expedition under your charge on the route from Indianola to San Antonio de Bexar, and was found extending in that direction from the Guadalupe River, in the vicinity of Victoria, W. N. W. to a point a few miles beyond Yorktown, occasionally interrupted, however, by several broad districts of fertile country. (*Vide Journal.*) Over this district it consists chiefly of coarse silicious sand, with pebbles and small boulders of silex and other rocks disseminated through it, the whole reposing on the Cretaceous marls and clays.

Between San Antonio and the Guadalupe Mountains, deposits apparently of the same geological age are of frequent occurrence. At several points west of the Rio Pecos they present a thickness of more than a hundred feet, and are to be traced almost uninterruptedly from near the Horsehead Crossing of that stream to the Guadalupe Mountains, a distance of nearly a hundred and fifty miles.

Source.—As has already been remarked, these deposits become thicker and the materials coarser in proportion as we travel from east to west. There can, therefore, hardly be a doubt as to the direction whence they were derived. Indeed in several instances we have succeeded in tracing them for hundreds of miles to their original beds. Thus heavy accumulations of rolled fragments of white limestone and sandstone, agreeing precisely in lithological and paleontological characters with the Upper Carboniferous limestone and sandstone of the Guadalupe Mountains, are found overlying the clays and sandstones of the Cretaceous System far to the east of that range, and no deposits of the same kind have been encountered west of it. (*Vide Journal.*)

Accumulations of rolled fragments of red porphyry and granite, presenting the same character as those of the Witchita Mountains, and which, as far as our own observations extend, are peculiar to that range, occur many miles to the eastward, but at no point west of these mountains have we succeeded in detecting any traces of them.

We have thus far spoken of the Boulder Formation only as it occurs east of the Rocky Mountains. We have, however, strong evidence of its existence much farther west. To the same geological period we would refer those extensive accumulations of loose materials which constitute the basins between the Guadalupe and Mimbres mountains. They consist chiefly of sands, clays, and coarse gravel, which have evidently been derived from the rocks, both stratified and unstratified, of the neighboring mountains. In

some of these valleys their thickness cannot fall far short of four or five hundred feet. At the Artesian Well, a few miles west of Fort Fillmore, they were penetrated to the depth of two hundred and fifty-eight feet without reaching their base, and a little farther north, at the San Diego Mountain, vertical sections are exposed to the height of near five hundred feet. (*Vide Report on the Jornada del Muerto.*)

Economic Uses.—Should it ever become necessary to construct macadamized roads over any portion of the region in which the boulder formation occurs, it would furnish excellent materials for that purpose. The limestone boulders would also form a good quicklime, and the sand would be well adapted for mortar.

TERTIARY SYSTEM.

We have been able to detect strata of the Tertiary Period only in two localities throughout the entire district under examination, and even in these the formation is developed upon comparatively an insignificant scale, extending over very limited areas, and attaining a vertical thickness of merely a few feet. Both localities where we have recognized it are in Southern Texas. One is situated thirty-five miles southeast of San Antonio, and was crossed by the Expedition on the 9th and 10th of April, 1855. (*Vide Journal.*) The Tertiary Strata present here a thickness of about twenty feet, and repose unconformably partly upon the sandstones and grits of the Coal Measures and partly upon the marls of the Cretaceous System. The rock is a dirty ferruginous limestone of a deep yellow color, and varies much in compactness, some of the layers being quite soft and crumbling, and others hard and breaking with an uneven fracture. It contains fossils in great abundance ; but they are usually casts, and so badly preserved as not to permit us to determine accurately their specific characters. They belong mostly to the genera *Tellina*, *Arca*, *Infundibulum*, *Fusus*, and *Natica*.

The next locality at which Tertiary Strata were observed is on Leon Creek, a few miles west of San Antonio. Here it consists of light gray earthy limestone, which is scattered at several points over the surface.

Although we have not seen Tertiary Strata in other localities than those just mentioned, there is reason to believe that they are of extensive occurrence in Eastern and Northeastern Texas. Dr. F. Roemer mentions the occurrence of this formation on the Brazos River near the town of Caldwell, and also in the vicinity of Nacogdoches. Assuming this last point as the extreme northeastern limit, it would give to this formation in Texas a northeast and southwest range of about three hundred miles. Nevertheless, as extensive as are these limits, we are of opinion that they include only a portion of the Tertiary area of this region, and that more extended research will develop its existence as far south as the Rio Grande.

CHAPTER II.

SECONDARY PERIOD.

CRETACEOUS SYSTEM.

The next formation that we meet, in descending order, in the district under consideration, is the Cretaceous System, which, on account of its great development upon the Western Plains, is far more important than any we have described. The strata of this system here exhibit the enormous thickness of three thousand six hundred feet, and occupy an area of many thousand square miles. With some local exceptions, they cover nearly the whole of the rectangular space included between the 29th and 39th degrees of latitude and the 99th and 105th degrees of longitude, extending southeast into the States of Louisiana, Mississippi, and Alabama, and north into the Territories of Kansas and Nebraska.

In the southern part of the district we have traced them almost continuously from near Victoria on the Guadalupe River in a course nearly W. N. W. to within a few miles of the southern extremity of the Guadalupe Mountains, and thence southward along the base of the Limpea Mountains. Farther north we have encountered them at Fort Towson, Fort Washita, Preston, the Cross Timbers of Texas, and throughout the entire country watered by the Big and Little Witchita, and the upper portions of the Trinity, Brazos, and Red Rivers. Along the Canadian River they have been met with by Mr. Marcon,* and north of that stream by Maj. Emory, Lieut. Simpson, Lieut. Abert, Capt. Stansbury, and other explorers.

In the Horse Mountains, and at several other points west of the Guadalupe Mountains, the Cretaceous rocks have likewise been encountered, but we have met with no proofs of the existence of deposits of this age in any portion of the region explored by ourself west of the Rio Grande. North of this, however, along the 35th parallel of latitude, they have been observed by Mr. Jules Marcon, and from the explorations of others we have abundant evidence of their existence in detached basins as far west as the Pacific coast. Dr. John Evans, U. S. Geologist, has recognized well marked Cretaceous strata at a number of points in Oregon and as far west as Vancouvers Island.

The Cretaceous Formation of our district may be separated by well marked lithological characters into two principal groups, viz.:

1. Upper Cretaceous or Calcareous Group.
2. Lower Cretaceous or Marly Clay Group.

* These rocks have been described by Mr. Jules Marcon as belonging mostly to the Triassic and Jurassic Systems, but evidence of their Cretaceous age will be presented farther on.

1. UPPER CRETACEOUS OR CALCAREOUS GROUP.

LITHOLOGICAL CHARACTER.

This division of the Cretaceous System consists chiefly of limestone and sandstone, of which the former is much the most abundant and varies much in character. It presents every degree of compactness, from soft chalk to hard subcrystalline limestone. It is, however, generally compact, of a dull earthy appearance, and varies in color from pure white through shades of light gray, yellow, blue, and brown. In many localities it contains a good deal of silex, or sometimes passes into pure silicious sandstone; in others it exhibits a more or less argillaceous character, though beds of clay are rarely observed in it.

The strata are sometimes cherty, and often, especially in the southern extension of the formation, they are crowded with light gray, blue, and dark nodules of flint from one to six inches in diameter. These are sometimes arranged in nearly parallel bands, but more frequently scattered promiscuously through the strata, now and then occurring so abundantly as to form a kind of conglomerate. As we travel north, the Cretaceous strata assume a much more arenaceous character, so that near the headwaters of Red River they are composed almost exclusively of silicious sandstone. But generally the sandstone alternates with the limestone in bands of from twenty to one hundred feet in thickness. It is usually highly ferruginous, and often contains spherical concretions of iron. Its color varies from light gray to deep red and brown. In some localities it is quite hard, durable, and possesses all the requisites of a good building material, but it is often soft and yields readily to the action of the weather.

RANGE, EXTENT, AND THICKNESS.

This division of the Cretaceous System has heretofore been regarded as occupying a comparatively limited portion of the region under consideration. From our own observations, however, taken in connexion with those of other explorers, we are convinced that its real importance in this respect has been greatly underrated, and that instead of being confined merely to isolated and distant points, it really constitutes the prevailing formation over a very large portion of the Plains.

Commencing in the southeast, these rocks occur at a number of points along the route traveled by your Expedition between Victoria and San Antonio. They do not, however, present here a vertical thickness of more than twenty or thirty feet, and are confined to limited areas.

In the vicinity of San Antonio the Upper Cretaceous strata occur in

gently-rounded hills and bold escarpments about two hundred feet in height, but as we travel westward from this place they increase rapidly in thickness, and at the San Pedro or Devils River, as well as at other points, they show a vertical development of upwards of a thousand feet, and constitute the prevailing surface formation until we arrive within a few miles of the Horse-head Crossing of the Rio Pecos. West of this point they are observed at frequent intervals as far as the sources of Delaware Creek, twenty-one miles east of the Guadalupe Mountains, and in this vicinity exhibit a thickness of five or six hundred feet. (*Vide Journal.*) Farther south their development is equally well marked along the base of the Limpea Mountains, as well as at several intermediate points.

On our return route from the Rio Pecos by way of Fort McKavett, Fort Mason, and Fredericksburg, they are the prevailing rocks as far as San Antonio, being interrupted occasionally by igneous protrusions, upheaved strata of the Paleozoic Period, and bands of red marls of the Lower Cretaceous Group. At several localities along this route the thickness of the Upper Cretaceous strata was estimated at about eleven hundred feet.

North of this route we find these rocks also well developed. From Fort Towson to Fort Washita, and thence in a southwest direction, they are traced almost uninterruptedly as far as the Upper Cross Timbers of Texas. In the vicinity of Fort Washita, and at several localities between that point and the Cross Timbers, they exhibit a vertical thickness of three or four hundred feet, though in this part of the district their usually observed thickness is from one to two hundred feet.

Along the Big and Little Witchita Rivers these rocks form abrupt and gently-rounded hills from four to five hundred feet high. On the Upper Brazos River they occur in elevated plateaus, and near the head of that stream appear in nearly perpendicular escarpments six or seven hundred feet high, forming here those high table lands that stretch away for many miles to the north, south, and west.

Again, these rocks are equally well developed in the region watered by the Upper Red River. Near the source of the Ke-che-ah-que-ho-no, or main branch of Red River, they exhibit a thickness of about six hundred feet, and form the bold escarpments which there characterize the eastern borders of the Llano Estacado.

Finally, other observers have shown the existence of the rocks of this division of the Cretaceous System along the Canadian River, and at a number of points north of that stream.

LOCAL DIFFERENCES.

In the vicinity of Fort Washita the Upper Cretaceous Limestone is usually hard, fine textured, and sometimes more or less crystalline. Its color varies from light gray to blue, yellow, and brown, and not unfrequently it is pure white.

Near the town of Preston, and at a number of localities between that place and the Upper Cross Timbers of Texas, it is soft, highly argillaceous, and crumbles rapidly on exposure to the weather.

On the Big and Little Witchita and Upper Brazos Rivers, it is hard, thin bedded, and of a dull light gray color, while along the Upper Red River it becomes more or less arenaceous, often passing into pure sandstone, which not unfrequently contains numerous nodular concretions of iron.

Farther south, along the route traveled by our Expedition between Victoria and San Antonio, and at various points west of the first crossing of the Rio Pecos, it is dull white, soft, and resembles pulverized chalk. At San Antonio, Fort Inge, and Fort Clarke, it is white or light gray, earthy in texture, and quite soft when first taken from the quarry, but possesses the valuable property of hardening upon being exposed for a short time to the action of the weather.

On the Rio Seco it is a dull white, soft, and cannot be distinguished from chalk. On the Arroyo Pedro it is of a light fawn color, compact, and breaks with a conchoidal fracture.

At several localities between San Antonio and San Pedro or Devils River it is a buff, compact calcareo-magnesian limestone. Between the San Pedro and Pecos Rivers it is sometimes hard. ferruginous, and contains a great abundance of flints, while in other localities it is more or less arenaceous, and at times passes into a pure sandstone.

Near the mouth of Delaware Creek it is a hard limestone, full of small, rounded cavities, and of a light cream color; but towards the sources of that stream the strata are thin bedded, of a light gray color, and appear to be undergoing rapid disintegration. South of this stream they are both compact and porous and sometimes crystalline.

PALEONTOLOGY.

Many of the organic remains such as collected by your Expedition from the upper division of the Cretaceous System have been described by Dr. Ferd. Roemer in his excellent and finely illustrated work on the Cretaceous Strata of Texas. We are able, however, to considerably augment the list by the addition of a number of new and interesting forms, which have been placed in the hands of a paleontologist for examination and description. We will, therefore, at present merely enumerate some of those species which have been found most characteristic of the mass.

The following species have been found to range from the top to the base of the formation: *Gryphœa Pitcheri* (Morton), *Exogyra arietina* (Roemer), *Janira Texana* (Roemer sp.), *Janira quadricostata* (Sowerby), and *Terebratula Wacoensis* (Roemer).

In the upper part of the formation we find most commonly the following, and as far as our observations extend they are peculiar to it: *Ceratites*

(*Ammonites*) *Pedernalis* (Roemer sp.), *Pterodonta subforsiformis* (B. F. Shumard), *Pleurotomaria crotaloides* (Morton), *Scalaria vertebroides ?* (Morton sp.), *Natica* (*Globiconcha*) *tumida* (B. F. Shumard), *Natica elevata* (B. F. Shumard), *Monopleura Texana* (Roemer), *Lima Wacoensis* (Roemer). *Ostrea crenulimargo* (Roemer), *Ostrea carinata* (Lamarck), *Panopœa Texana* (B. F. Shumard), and *Astrocœnia Guadalupœ* (Roemer).

In the inferior strata the most characteristic forms are: *Ammonites vespertinus* (Morton), *Ammonites Popeanus* (B. F. Shumard), *Turrilites Brazoensis* (Roemer), *Baculites asper* (Morton), *Exogyra costata* (Say), *Exogyra arietina* (Roemer), *Exogyra lœvinsculd* (Roemer), *Ostrea vesicularis* (Lamarck), *Gryphœa Pitcheri* (Morton), *Pecten* (sp. undt.), *Janira quadricostata* (Sowerby), *Inoceramus Cripsii* (Mantell), *Inoceramus mytiloides* (Mantell), *Inoceramus* (sp. undt.), *Pholadomya elegantula* (D'Orb), *Cardium elegantulum* (Roemer), *Cassidulus œpuoreus* (Roemer), *Terebratula Choctawensis* (B. F. Shumard), *Nerinea Texana* (Roemer), and *Trigonia* (nor. sp.).

It will be seen from the above list of species that with some few exceptions the fossils of the superior and inferior portions of the Upper Cretaceous strata of Texas and New Mexico are quite distinct. Nevertheless, as we cannot draw a well marked horizon by lithological characters, we have thought proper to make no separation of the strata.

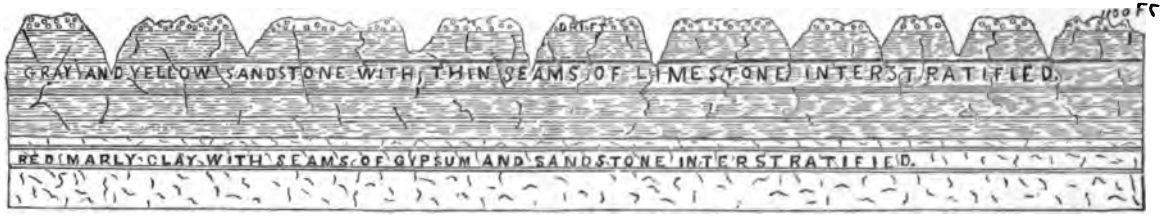
PHYSICAL FEATURES.

This formation more than any other of the Plains is characterized by lofty and rough precipices and deep and fearful canyons. The elevated plateaus, which sometimes attain an altitude of seven or eight hundred feet, and often are seen stretching across extensive districts of country, present everywhere rough and precipitous cliffs, with sometimes nearly vertical faces, showing almost at a single glance the entire thickness of the formation.

Section No. III, taken from near the headwaters of the *Ke-che-ah-que-ho-no*, or main fork of Red River, presents a remarkable example of the kind. Here the elevated plateau known as the Llano Estacado terminates abruptly in a line of escarpments from six to eight hundred feet in height. These are for the most part nearly vertical, and extend north and south for a distance of over thirty miles. From their bases there is a descent of about four hundred feet by a succession of abrupt terraces of gypsum, red marly clay, and sandstone, so that we have here in a single locality an exposure of eleven hundred feet of Cretaceous strata.

Section No. IV was taken from near the sources of the main branch of the Brazos River, and exhibits another marked example of the kind. The table land of which this escarpment forms the abrupt boundary has an elevation above the bed of the river of about eight hundred feet, and presents a smooth and nearly flat surface on the top, covered with short yellow moss-like grass and a scattering growth of Mezquite trees. These cliffs are

No. III.
Section of Bluffs on Ke-Che-Ah-Que-Ho-No or Main Branch of Red River.



No. IV.
Section of Bluff near the head waters of the Brazos River, Texas.

nearly vertical, and form a continuous line thirty or forty miles in length, and throughout nearly the whole of this distance the edges of the limestone strata are finely exhibited, resting on the red marly clay and its intercalated sandstones. The lower plains extending east of this line of cliffs, say for fifty or sixty miles, are marked with small plateaus and truncated conical hills of the same strata as compose the main table land, with which doubtless they were at one time continuous.

The cliffs near the Rio Pecos, known as the "Castle Mountains," and the succession of abrupt terraces encountered on the route of the Expedition between San Antonio and the San Pedro River, and described in the Journal of this report, afford other examples similar to those presented by Sections III and IV. The "Castle Mountains," which are over sixty miles in length, are nothing more than the precipitous borders of an elevated plateau, which stretches thence in an easterly and southeasterly direction for many miles.

Canyons.—Another very important characteristic of this formation is its numerous and remarkable canyons. The most extensive of these with which we are acquainted are those of the San Pedro and Red Rivers. Both of these, as well as others so frequently met with in this region, have been hollowed out of the solid strata of the table lands by the erosive action of water so as to exhibit on either side abrupt and often perpendicular walls seven or eight hundred feet high.

The Canyon of San Pedro River is about sixty-five miles long, and varies from a few hundred yards to several miles in width. The walls of this immense chasm are often deeply fissured, and composed of variously colored limestone in nearly horizontal beds. The river, which winds its way through the canyon, is now comparatively a very insignificant stream, usually not exceeding fifteen or twenty yards in width, with a depth of three or four feet.

The canyon in which the *Ke-che-ah-que-ho-no*, or main trunk of Red River, takes its rise, has been already graphically described by Capt. Marcy.* It is scarcely less extensive than the Devils River Canyon, being about sixty miles in length. On either side are nearly vertical walls of limestone, sandstone, gypsum, and red marly clay, from five to eight hundred feet high. The strata are in nearly horizontal beds, often traversed by deep fissures, and the main chasm is intersected at various points by tributary canyons, some of them several miles long. This gigantic canyon has been produced by the erosive action of the river, which winds through its entire length and finally emerges into the open plain, whence it flows for many miles along the base of the escarpment which forms a portion of the eastern boundary of the Llano Estacado.

Other canyons scarcely less extensive are described in the Journal of this

*Report on Red River of Louisiana.

report. These are often exceedingly rugged, and though generally very tortuous, all of them appear to have a general east and west direction; hence they would afford no very serious obstacle to the construction of a railroad to the Pacific.

Denudation.—Besides its numerous escarpments and canyons there are other phenomena in the region we are considering showing the great extent to which the strata of this formation have been removed by denuding agencies. There can be no doubt that the Upper Cretaceous strata at one period occupied almost the entire space included between the western borders of the settlements and the Rocky Mountains. Some of the facts upon which this opinion is based are given in detail in the accompanying Journal, and others equally conclusive are abundantly exhibited along the Colorado, Big Witchita, Upper Brazos, and Red Rivers, and at many points north of these streams. The isolated, truncated, conical hills we have so frequently encountered, and which are described by travelers as constituting one of the most characteristic features of a very considerable portion of the Plains, are nothing more than the remains of a once continuous plateau that has gradually been removed by erosion. These are often six or seven hundred feet high, and in many instances almost wholly composed of nearly horizontal strata of the Upper Cretaceous Group. They are often widely separated from each other, and as already instanced on the Brazos River, sometimes fifty or sixty miles distant from the table lands which they once formed a part. Sections . . . . and . . . . of the Journal exhibit the character of some of these hills.

Disturbance.—As will have been gathered from the foregoing remarks, the Upper Cretaceous formation exhibits generally but little evidence of violent disturbance in the district we are noticing. The strata are usually spread out in smooth parallel layers, which usually conform to the general slope of the country. The only localities in which we have observed them violently dislocated or contorted are in the southern extension of the formation; as along the base of the Limpea Mountains; near the mouth of Delaware Creek; a few miles west of Castroville; on the San Saba and Frio Rivers; and in the vicinity of Forts Inge, Clarke, and Mason. Of these the most important is that near the Limpea Mountains, where the strata are seen contorted, fractured, and inclined against eruptive rocks at angles of from 30 to 50 degrees. The next in point of importance are the disturbed districts of Fort Mason and the San Saba River, which appear to occupy extensive areas. These are elsewhere described in this report.

ECONOMICAL GEOLOGY.

BUILDING MATERIALS.

Many of the beds of the Upper Cretaceous Group afford excellent materials for construction, for which purpose they are already largely employed in the settled portions of Texas. They are usually very easily wrought, and often combine firmness, beauty, and great durability; hence they are exceedingly valuable for the construction of public works. Some of the most useful varieties have been indicated in the Journal. The rock quarried near San Antonio, Fort Inge, and Fort Clarke, is, on account of its beauty and property of acquiring hardness upon exposure to the atmosphere, peculiarly valuable.

Quicklime.—By burning, an excellent quality of quicklime for mortar can almost always be obtained from the limestone of this formation.

ROAD MATERIALS.

For the construction of macadamized roads upon the Plains this formation will furnish materials in great abundance. In making selections the hard cherty varieties of limestone should always be preferred when they can be readily obtained.

USEFUL MINERALS.

Chalk.—This important article exists in great abundance on the Rio Seco, and is also believed to occur in the neighborhood of Fort Clarke. It is generally much less pure than the foreign article, but may be made to answer many of the purposes for which the latter is employed.

Lithographic Limestone of very fair quality occurs on the Arroyo Pedro. Some examples obtained from that locality are hard, compact, and susceptible of a very good polish, but contain minute veins and crystals of calcite, which would interfere very materially with the usefulness of the rock for lithographic purposes. Others, however, are perfectly homogeneous in texture, possess a light uniform color, and present all the requisites of a good lithographic stone.

Calcareous Marl.—This valuable fertilizer occurs in the greatest abundance throughout almost the entire region occupied by the Upper Cretaceous strata. In many instances it is composed of nearly pure carbonate of lime, existing sometimes in beds thirty or forty feet in thickness. Could means be devised for transporting it to market, it would prove of inestimable value.

METALLIC ORES.

The only ores of this formation of sufficient importance to require notice are those of iron. This metal is disseminated through the different layers, principally in the form of oxides and the bisulphuret or iron pyrites.

Oxides of Iron.—The coloring matter of most of the limestones and sandstones is due to the oxides of iron, which also exist in the form of spherical concretions, which are sometimes so abundant as to impart to the rock a highly mottled appearance. Brown Hematite of very fair quality is found in beds of considerable thickness in connexion with these rocks along the Upper Brazos River.

Bisulphuret of Iron (*Iron Pyrites*), in cylindrical and globular masses, often studded with beautiful crystals, are of frequent occurrence in the limestone.

AGRICULTURAL CHARACTER.

By far the largest portion of the rich agricultural district of Texas is comprised within the limits of this formation. Whenever favorably situated for natural irrigation the soil derived from these rocks is usually highly productive and well adapted for the growth of the great staples, corn, cotton, wheat, tobacco, and almost every product suited to the climate. But as we have already spoken of this subject in detail in connexion with the quaternary deposits and in the Journal, it is unnecessary to pursue it any farther at present.

SPRINGS.

Although not generally so abundant as we might be led to suppose from the character of the rocks, springs are nevertheless of frequent occurrence in various portions of the region occupied by this formation. Indeed in some instances they furnish almost the only supply of water over districts of country hundreds of miles in extent. They are sometimes unusually large, and generally much more abundant near the base than towards the summit of the formation. The springs in the vicinity of San Antonio and Fort Washita issue from near the junction of the limestone with the underlying marly clay, and afford streams of considerable magnitude. The San Antonio, Guadalupe, Frio, Seco, Medina, San Pedro, Concho, San Saba, False Washita, Brazos, and Red Rivers all originate from springs that gush from the Upper Cretaceous strata.

Subterranean Rivers are known to occur in connexion with these rocks in several parts of Texas. The most remarkable one known to us was discovered near the northern base of the Limpea Mountains by Mr. Thompson, a member of your Expedition. This stream emerges from a triangular

opening in the strata, and after flowing about a hundred yards through a basin-shaped depression in the prairie, again disappears beneath massive strata of limestone. Near the point of emergence it is about fifty feet wide, ten feet deep, and flows with a rapid current, but contracts somewhat in width a little lower down. It abounds in fish of the same species as are usually found in the streams of Texas.

CHAPTER III.

2. LOWER CRETACEOUS OR MARLY CLAY GROUP.

LITHOLOGICAL CHARACTER.

The inferior division of the Cretaceous System is composed chiefly of marly clay, sandstone, and gypsum. The clay and sandstone occur in alternating beds of variable thickness, and constitute the chief mass of the formation; the gypsum usually occurs towards the top, and is either found upon the surface or interstratified with the clay in nearly horizontal bands.

The Marly Clay varies considerably in lithological character, and, as the name implies, it is composed mainly of clay and carbonate of lime combined in different proportions, with which there is frequently a large admixture of sand and gypsum. The prevailing color is a deep venetian red, often elegantly variegated with various shades of blue, brown, and yellow. It is for the most part highly indurated, and sometimes exhibits a schistose structure not unlike the shales of the Coal Measures. In some localities, particularly towards the western boundary, it abounds in small rounded pebbles of granite, porphyry, quartz, and other eruptive rocks. Near the upper part the layers are often beautifully reticulated with gypsum.

The Sandstone passes from a fine-grained variety to coarse gritstone, and its colors are dark purple, red, brown, yellow, gray, and white. In many instances it is thickly marked with small circular light yellow and greenish spots, which are distributed through all the beds. The layers are often finely laminated, and sometimes contain rounded pebbles of eruptive rocks and nodular concretions of iron. The sandstone often contains a good deal of calcareous matter, and sometimes passes gradually into limestone. Usually it is quite soft, being in many instances but little more than slightly coherent sand, which crumbles more or less rapidly when exposed to the weather.

The Gypsum is mostly white, amorphous, and occurs in layers, sometimes of enormous thickness. This rock will be more particularly described under the head of useful minerals.

EXTENT AND THICKNESS.

The Marly Clay Group attains a vertical development of several thousand feet, and as far as our observations have extended, forms, with a few local exceptions, the prevailing formation of all that portion of the Plains east of the Rocky Mountains not included within the limits of the superior division of the Cretaceous Group. It is exposed at various points subordinate to

the last, and is well ascertained to occur as far east as Fort Washita, in the Chickasaw Territory.

Beginning in the southern part of the district under notice, we find this formation well developed along the route traveled by your Expedition between Victoria and San Antonio, Texas, where it is frequently exposed in natural sections from fifty to a hundred feet high. Near San Antonio it has been artificially excavated in one place to the depth of a hundred and ten and in another to a hundred and fifty feet without reaching the base. Immediately west of this it disappears beneath the rocks of the Upper Cretaceous Group, and does not again show itself in that direction, save at a few isolated points, until we arrive at the abrupt escarpments known as the "Castle Mountains," near the base of which it is seen reposing in nearly horizontal layers (*vide Journal*), thence westward it forms, with the exceptions pointed out in the preceding chapter, the only rocks to be seen until we approach the sources of Delaware Creek, where it is succeeded by the Paleozoic rocks.

West of the Guadalupe Mountains we again observe the Marly Clay Group, but here it is developed upon a very limited scale, being only a few feet in thickness, and confined to a strip of country not exceeding fifteen or twenty miles in width. West of this we have not been able to recognize positively its existence over any portion of the region explored by ourselves, but from the examinations of others it is highly probable that it appears in detached basins over a large portion of the region comprising the Western or Pacific Slope of our continent.

Farther north we have ascertained its existence at Fort Washita, at several points between there and the Upper Cross Timbers of Texas, and throughout the greater portion of the region watered by the Big and Little Witchita, Upper Brazos, and Red Rivers, and still farther north it has been encountered by Capt. Marcy, Lieut. Simpson, Mr. Marcon, Col. Long, and numerous other explorers.

Thickness.—As deep natural sections are very rarely observed in this formation, we can merely estimate its thickness approximately. As already stated, it has been artificially excavated in the vicinity of San Antonio to the depth of a hundred and fifty feet without reaching the base. Near Fort Washita it is exposed in natural sections sixty or seventy feet high. At the first Artesian Well, located upon the Llano Estacado, about fourteen miles east of the Rio Pecos, the Marly Clay formation was penetrated to the depth of six hundred and forty-one feet, and at the second one, located a few miles farther south, the borings were carried to the depth of eight hundred and fifty-eight feet, and in neither instance was the base of the formation reached. On the Big and Little Witchita and Brazos Rivers it forms bluffs from two to five hundred feet high, while along the Upper Red River its general thickness, estimated after an examination of numerous sections, cannot be less than two thousand five hundred feet. This is

the thickness which we have accordingly given it in the general vertical section; nevertheless it is proper to state that at no point on Red River were we able to see the base of the formation, so that even this enormous thickness may prove to be an underestimate.

PHYSICAL FEATURES.

The principal distinguishing features of the district occupied by this formation are a gently undulating surface, low ridges often with precipitous sides, and abrupt truncated conical hills. The surface of the country is usually of a deep red color, and the hills and ridges, being composed chiefly of clay and sandstone in alternating and nearly horizontal bands, exhibit a remarkably striated appearance. Owing to the general softness of the strata composing this formation, the beds of the principal rivers are generally broad and deeply sunk below the general level of the country, and the clay mixing with their waters in the form of sediment tinges them their characteristic red hue.

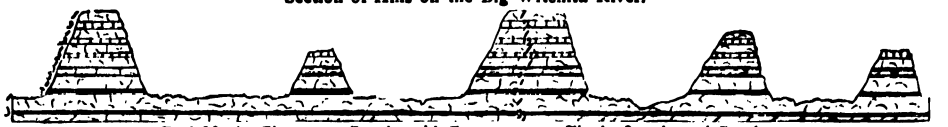
This division of the Cretaceous System, like the preceding, exhibits evidence of denudation on a grand scale. The different hills and ridges, which form such a striking feature in the otherwise monotonous scenery, are the remains of once continuous strata which have been gradually eroded. Many of these hills are four or five hundred feet high. They are, as already remarked, usually isolated and rise abruptly from the surface of the prairie in the form of truncated cones, their summits being usually smooth, flat, and covered with short grass. The accompanying section (No. V) exhibits the geological character of these hills as they occur along the Big Witchita River.

In addition to the above phenomena, there are others of a less general character that serve occasionally to relieve the dull uniformity of the region occupied by this formation. The sandstone and clay, being of unequal hardness, weather unevenly, and the former is sometimes seen projecting in a series of shelves several feet from the face of the bluffs. At other points we observe detached layers of sandstone ten or fifteen feet in diameter supported several feet from the ground on slender pedestals of clay, as exhibited in the following section [No. VI] taken from near the source of the Little Witchita River.

Caverns and deep pits are of frequent occurrence in the gypsum, the former sometimes extending many feet. The pits are usually quite smooth and funnel-shaped.

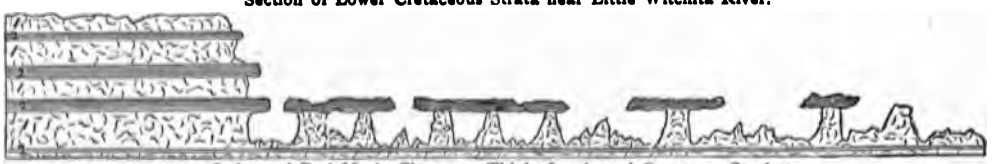
Dip.—These strata exhibit little evidence of violent disturbance, and are usually found dipping at very slight angles E. S. E. In a few instances they are undulated and unheaved, but these are mere local exceptions.

No. V.
Section of Hills on the Big Witchita River.



1. Red Marly Clay. 2. Saccharoid Gypsum. 3. Finely Laminated Sandstone.

No. VI.
Section of Lower Cretaceous Strata near Little Witchita River.



1. Indurated Red Marly Clay. 2. Thinly Laminated Quartzose Sandstone.

ORIGIN.

The materials composing the larger portion of the Marly Clay formation have been deposited in the bottom of the ocean in the condition of fine sediment, which appears to have been derived chiefly from the destruction of the granites and porphyries that we find towards the western slope of our continent. These are generally of a deep red color, and their disintegration produces materials similar to those constituting the larger part of the Marly Clay formation. The great thickness and extent of this group, covering, as it does, many thousands of square miles, seems to preclude the idea of its having been derived from the destruction of the rocks of the Plains east of the Rocky Mountains, since granites and porphyries that would produce such a deposit are there of uncommon occurrence. Moreover, we find in the marly clay and sandstone, pebbles identical in composition and appearance with the granites and porphyries that form the eruptive ranges towards the western side of the Continent. These pebbles also increase in size and number as we advance in that direction, and the formation itself is greatly increased in thickness. At Fort Washita it is probably not more than a hundred feet thick, while farther westward it is estimated to be not less than twenty-five hundred feet thick.

PALEONTOLOGY.

This formation has been described by Mr. Marcon as belonging partly to the Jurassic and partly to the Triassic Systems. Under the Jurassic he includes a large proportion of the strata described in the preceding chapter, while the Triassic is made to occupy, with a few local exceptions, not only all that portion of the Plains east of the Rocky Mountains not included within the limits of his Jurassic, but also a very extensive area in other parts of the United States.

The data for these conclusions appear to have been derived mainly from the region along the Canadian River, explored by Lieut. Whipple's party, of which Mr. Marcon was a member. Our observations on the geology of the Upper Red River country have also been brought forward in support of these views. Inasmuch, however, as we cannot agree with this geologist in his opinions respecting the parallelism of these strata, we shall proceed to consider a portion of the evidence that has led us to refer the Marly Clay formation of this and other portions of the Plains to the Cretaceous Period.

In the first place we would premise, that with the exception of the gypsum, which is confined to the superior part of the mass, we have not been able to detect any permanent characters that will warrant us in separating the Marly Clay formation into distinct groups. Nearly all the main features mentioned by Mr. Marcon as characterizing the divisions proposed by

him, we have found to occur indiscriminately throughout the entire thickness of the formation.

While engaged in the exploration of Upper Red River under Capt. R. B. Marcy, fossil shells, principally *Gryphæa Pitcheri*, and fragments of silicified monocotyledonous and dicotyledonous fossil wood, were, upon several occasions, observed in the upper part of the Marly Clay formation; but as these appeared to be worn by attrition, and were also abundantly distributed through the overlying Quaternary drift, little attention was at that time paid to them. During the same journey we also found in the clay, considerably below the surface, a fossil coral, which Prof. Hitchcock refers to the genus Scyphia, and which he regards as being closely allied to species that are characteristic of the Cretaceous rocks in other parts of the world.

Subsequently, while exploring near the sources of the Brazos and Big and Little Witchita Rivers, we again found the same shells in the Marly Clay formation, many feet below the top, associated with *Ostrea* and other forms that we have since detected in the Upper Cretaceous limestone farther southward.

The fossil wood mentioned by Mr. Marcon as occurring so abundantly along the Canadian, and which, we presume, is the same as we have obtained on Red River, only a few miles farther south, cannot be relied upon as evidence of the Triassic age of the Marly Clay formation, since fossil wood occurs abundantly in the Cretaceous rocks of Texas, as will be seen by referring to the Journal of this report, where it is mentioned that specimens were encountered at frequent intervals along our route from Indianola to El Paso. On the Frio and Nueces Rivers fragments of the trunks of trees, some of them several feet in length and weighing over five hundred pounds, were observed. After a careful comparison of some of these specimens with those obtained from the Brazos and Red River country, we are unable to detect any difference whatever. Fossil wood is also mentioned by Roemer and other explorers as occurring abundantly in the Cretaceous strata of Texas. The evidence derivable from fossil wood is therefore altogether in favor of the Cretaceous age of the Marly Clay formation of the Canadian and Red Rivers.

At Fort Washita the layers of the inferior part of the Cretaceous Group contain *Ammonites*, chiefly *A. vespertinus*, in a good state of preservation. These are confined principally to the clay, the included layers of sandstone being almost entirely destitute of organic remains.

The shell figured by Mr. Marcon as *Ostrea Marshii*, and regarded by him as characteristic of the American Jurassic, we have found in the Upper Limestone of Fort Washita, in the same beds with *Gryphæa Pitcheri*, *Hemiaster elegans*, *Holaster simplex*, and *Ammonites vespertinus*. This shell was described under the name of *Ostrea subovata*, by Dr. B. F. Shumard, in Capt. Marcy's Report of the Red River of Louisiana (p. 205, pl. 5, fig. 2), who regards it as being quite distinct from *O. Marshii*, though it is doubtless a closely allied

species. At the same locality we have found in the clay and overlying limestone examples of Gryphæa, which present no specific differences from those figured by Mr. Marcon as *G. dilatata* (*G. Tucumcari*), which this author considers peculiar to the so-called American Jurassic. These difficulties can hardly be reconciled unless we refer the upper rocks of Fort Washita, with their rich array of well-marked cretaceous fossils, also to the Jurassic.

That the clays and sandstones of Fort Washita are really of the same geological age as those farther west, can, we think, hardly admit of a doubt. They are found reposing beneath the same limestone and rest immediately upon the Coal Measures, while their lithological characters are very similar, the only difference being in the color of the clay, which, at Fort Washita, is blue instead of red; but, as will be seen by referring to the Journal, this color also prevails to some extent towards the south and southwest.

Near San Antonio de Bexar well marked specimens of *Exogyra costata* and *Inoceramus crispii*, both of them highly characteristic fossils of the Cretaceous formation of Texas and various other portions of the United States, were obtained from near the bottom of the well, which was sunk in the marly clay to the depth of a hundred and fifty feet. (*Vide Journal.*) Specimens of *Exogyra costata* were also abundantly met with in the same formation a few miles west of San Antonio.

With the exception of that at Fort Washita, the best locality for fossils of the Marly Clay occurs near the Rio Pecos, and is mentioned in the notes of May 17, 1855. (*Vide Journal.*) Here the Marly Clay is well exposed, subordinate to thick strata of limestone, and is crowded with *Gryphæa*, identical with those figured by Mr. Marcon as Gryphæa Pitcheri, and which is admitted by him to be a cretaceous species. The same shell is well known to occur at many localities in the upper limestone of the Cretaceous Group throughout Texas.

In looking over the journals of other explorers we find still farther confirmation of the cretaceous age of this formation. Specimens of *Inoceramus*, and other fossils considered characteristic of the Cretaceous formation, were obtained by Lieut. Abert from near the Raton Pass, latitude 70 degrees 41 minutes, longitude 104 degrees 07 minutes, and at Pablozon, on the Rio Puerco. From the published notes of that officer we judge that one, and probably both, of these localities occur in the Marly Clay formation. Well marked specimens of Inoceramus of the Cretaceous System have also been obtained by Wislizenus and Lieut. Simpson along the valley of the Canadian River, only a short distance from Pyramid Mount, where the *Gryphœa Tucumcari* and *Ostrea Marshii*, mentioned by Mr. Marcon, were obtained. On the False Washita, near the Canadian River, *Gryphœa Pitcheri* has been observed in great abundance in the vicinity of extensive gypsum deposits. Cretaceous fossils were also procured by yourself from the vicinity of the Sulphur Springs of the Colorado. These last, however, as well as those procured by you from the neighborhood of the Sand Hills

of the Llano Estacado, may have been obtained from the rocks of the Upper Cretaceous Group.

Finally, among the host of fossils obtained from the Secondary Strata of Texas, New Mexico, and the adjacent Indian Territory, we are not aware that a single one has been found that is positively identical with either Triassic or Jurassic species of Europe. The *Ostrea subovata* (*O. Marshii*, Marcon) and *Gryphœa Tucumcarii*, mentioned by Mr. Marcon as occurring along the Canadian, were probably obtained from the Upper Cretaceous, as they occupy this position in other parts of this region.

The mere lithological character of these strata, so much relied upon by that author, cannot be taken as evidence of their being the equivalents of the Triassic and Jurassic Systems of Europe, though it is true they somewhat resemble the latter in mineralogical composition; but from the same kind of evidence we might, with equal propriety, regard them as being parallel with the Permian of Russia, the Tertiary of Auvergne, or the Carboniferous of Nova Scotia.

ECONOMICAL GEOLOGY.

BUILDING MATERIALS.

As a general rule the rocks of this formation possess very little firmness or durability, and are, therefore, but poorly adapted for building purposes or works of internal improvement. In some localities, however, the sandstone is moderately firm and resisting, and might, in the absence of better materials, be used for construction.

GYPSUM.

This mineral, on account of its economical value and enormous development upon the Plains, is of far more importance than any rocks we have considered. The Gypsum Field of the West, the great extent of which was published in 1852, shortly after the return to the States of the Red River Expedition, is believed to be the largest in the world, and will hereafter prove an inexhaustible source of wealth to the State of Texas and adjacent Territories.

The exact limits of the gypsum cannot at present be very accurately determined. It is well known to occur in great abundance at several points north of the Arkansas River, and on that stream it is mentioned by Col. Long and others. Thence southward it has been traced through the regions watered by the Canadian,* Red, Big and Little Witchita, Brazos, and Pecos Rivers to within a few miles of the northern base of the Limpea

* Reports of Capt. R. B. Marcy, Lieut. Simpson, and Mr. Marcon.

Mountains, with an average width east of the Rocky Mountains of perhaps not less than two hundred and fifty miles.

West of the Rio Grande gypsum is also met with in great abundance, and towards the south we have abundant evidence that it extends through various portions of Mexico. As already remarked, it occurs chiefly towards the summit of the Marly Clay formation, and is found either upon the surface or interstratified with the clay in successive and nearly horizontal layers of variable thickness. It usually occurs amorphous and pure white, more or less granular, and sometimes its texture is subcrystalline, resembling loaf sugar. Not unfrequently it passes into selenite, fibrous gypsum, or compact alabaster. In some localities it is much discolored with oxide of iron, in others it is variegated with various shades of green and blue by oxides and carbonates of copper. Between the beds the clay is often thickly reticulated with thin veins of selenite and fibrous gypsum.

The thickness of the different beds is sometimes enormous. On Red River they vary from a few inches to twenty-five or thirty feet. On Delaware Creek, a few miles below its source, bluffs of pure white gypsum are exposed to the thickness of about sixty feet, while between the Big Witchita and Brazos Rivers hills composed entirely of gypsum were encountered, whose heights were estimated by myself, as well as by several others of the party, at about seven hundred feet.

METALLIC ORES.

We have detected in this formation ores of Iron, Copper, and Manganese. Of these the most abundantly distributed are those of iron, which, in the form of oxides, furnish the principal portion of the coloring matter in the clays and sandstones.

Brown Iron Ore (*Brown Hemitite*) occurs in workable quantities in several localities along the Big Witchita River. It sometimes contains a large admixture of clay. In the form of Yellow Ocher, it is often used by the Indians as a paint.

Bisulphuret of Iron (*Iron Pyrites*) occurs in small crystals and spheroidal masses, occasionally disseminated through the clay. The spheroidal form is often beautifully studded with minute shining crystals, and when broken usually exhibits a fibrous radiated structure.

Ferruginous Sands of remarkable purity occur in great abundance on Cache Creek, an affluent of Red River. Specimens which we collected from this locality were submitted to Prof. C. U. Shephard for examination, and found to be composed of about equal proportions of tatiniferous and magnetic oxide of iron.* These sands have doubtless been derived from the Witchita Mountains.

*Marcy's Report of Red River of Louisiana.

Chloride of Copper (*Marcylite*).—Specimens of a dark colored compact mineral, very closely resembling black oxide of copper, were collected by myself from the Marly Clay formation on Red River, not far from the Witchita Mountains. Prof. Shephard, to whom they were submitted for examination, has pronounced them to belong to a new ore of copper, which he has named *Marcylite*, in honor of my friend Capt. R. B. Marcy. The following is the result of his analysis of the ore:

Copper	54.30
Oxygen and Chlorine	36.20
Water	9.50
	100.00

with traces of silica.

This ore, if obtained in sufficient quantity, would, on account of its richness, prove highly valuable. Only a few small specimens of it, however, were met with.

Oxides and Carbonates of Copper.—Small rounded masses of oxide and carbonate of copper of remarkable purity were observed abundantly distributed upon the surface near the sources of the Big Witchita and Brazos Rivers. We were unable to trace them to their source. Specimens of impure oxide and carbonate of copper have also been found in connection with the gypsum near the sources of the North Branch of Red River.

Several other varieties of copper ore have been met with in this formation along the Brazos and Red Rivers, but on account of their great impurity they do not possess much value.

Manganese.—Impure ores of this metal have been met with in two localities—one on the Witchita River, near its source, and the other on Copper Creek, an affluent of Red River. Specimens from the latter were examined by Prof. Shephard, and found to consist of Manganese in the state of binoxide with a very large percentage of silica and some peroxide of iron.

SALT (CHLORIDE OF SODIUM).

The only deposits of this character met with by myself occur in the southern part of the district, and are described in the Journal. From the observations of other explorers, however, I am inclined to believe that this valuable substance is of extensive occurrence in the country north of Red River. Mr. Marcon mentions thick deposits of rock salt in the Marly Clay formation along the Canadian, and it is known to occur in the greatest abundance N. W. of Fort Gibson, near the great bend of the Arkansas River.

SPRINGS.

One of the principal difficulties experienced by travelers upon that portion of the Plains embraced within the limits of the Marly Clay formation, is the great scarcity of water. This arises principally from three causes: first, the great deficiency in the annual amount of rain; second, the impermeable character of the clay, which allows most of the water that falls to be conducted off, either by surface drainage or by evaporation; and, third, the general absence of extensive faults or breaks in the strata, from which cause the water, after having once entered them, is often made to flow long distances through subterranean channels before finding an outlet.

Most of the springs examined by ourselves in this formation issue from near the top of the strata, and are consequently not of a very permanent character, usually drying up soon after the close of the rainy seasons. In some few instances, however, they were found to issue from much greater depths beneath the surface, and then they are larger and yield a more constant supply of water. Wherever the gypsum prevails the water usually possesses a nauseous and bitter taste. This appears to be owing mainly to the presence of salts of lime, magnesia, and soda. It is while flowing through the gypsum formation of the Plains that the waters of many of the larger rivers of Texas, such as the Red, Brazos, and Witchita, acquire their bitter taste.

CHAPTER IV.

PALEOZOIC PERIOD.

Lying unconformably beneath the rocks of the Cretaceous System, we have an assemblage of strata belonging to the Paleozoic Period, and composed, for the most part, of hard gray, blue, and white limestone; heavy bedded quartzose sandstone, conglomerate; millstone grit, and dark shales. Collectively they exhibit a thickness of between six and seven thousand feet, and are observed cropping out extensively both upon the eastern and western side of the Plains. On the east they are well exposed along the western borders of Iowa,* Missouri, and Arkansas, and through various portions of the adjacent Indian Territories, and are observed extending southward through Texas as far as Fort McIntosh, on the Rio Grande. West of these they constitute the great floor or trough upon which are deposited the newer formations of the Plains, and after disappearing beneath the latter, are not again met with, save at a few isolated points, until we approach within one or two hundred miles of the western borders of the Atlantic slope, where they rise majestically to the height of several thousand feet in lofty mountain ranges.

Near the western line of Arkansas they exhibit a vertical development of near four thousand feet, and constitute a large portion of the Ozark Range. Thence, with the exception of a granitic protrusion about twenty miles in width and the area covered by the Cretaceous deposits of Fort Washita and the Cross Timbers already mentioned, they are traced continuously west and southwest to Fort Gibson, Fort Belknap, and the Clear Fork of the Brazos.

On the western side of the Plains they constitute the floors of several of the principal valleys. They also form the Guadalupe, Sacramento, Robledo, Fra Cristoval, and a large portion of the Organ and Horse Mountains. North of the district examined by myself, the Paleozoic rocks have been frequently encountered by others. Mr. Marcon mentions their occurrence in the mountains near Albuquerque. Lieut. Simpson met with them in latitude 36 degrees 12 minutes, longitude 108 degrees 52 minutes; Lieut. Abert, in latitude 37 degrees 15 minutes, longitude 104 degrees 35 minutes; while still farther north they have been recognized by Emory, Fremont, Parker, Stansburry, and other explorers.

CARBONIFEROUS SYSTEM.

The rocks of the Carboniferous System are separated by their lithological and paleontological characters into two distinct and well defined divisions:

* Owns' Report.

1. Coal Measures, or Upper Carboniferous.
2. Mountain Limestone, or Lower Carboniferous.

1. COAL MEASURES.

LITHOLOGICAL CHARACTER.

The Coal Measures consist principally of limestone, sandstone, conglomerate, millstone grit, and shale. The limestone and sandstone exist in about equal proportions, and these constitute the chief part of the formation.

The Limestone is usually compact, subcrystalline, and occurs in strata of very variable thickness. Sometimes the layers are massive and many feet in thickness, but more frequently they are thin-bedded, and in some localities laminated or even foliated. The prevailing colors are light gray, blue, and brown. Occasionally they are dark gray and black, or, as in the Guadalupe Mountains, almost pure white. Veins of quartz sometimes traverse the strata from top to bottom, and in their western extension they are not unfrequently highly metamorphosed. In some localities they pass into nearly pure calcite, and in others they contain a great deal of chert.

The Sandstone is both massive and thin-bedded, and, in general lithological character, corresponds very closely with that of the Coal Measures of Illinois, Indiana, and Kentucky. It is both coarse and fine grained, more or less ferruginous, and exhibits every variety of hardness. Many of its layers are highly micaceous, and the rock often contains disseminated nodules of brown and black iron ore. In color it presents various shades of gray, yellow, brown, and black. The surface of the different layers are often beautifully ripple-marked. This rock sometimes passes into millstone grit and conglomerate, and, like the limestone, is not unfrequently traversed from top to bottom by tortuous veins of quartz.

The Millstone Grit generally occurs in thin layers, situated usually near the base of the sandstone, into which it passes by almost insensible gradations. It consists mostly of coarse quartz grains firmly cemented with silicious matter.

The Conglomerate of the Coal Measures has been observed only in Eastern Texas and the Choctaw Territory, where it sometimes presents a thickness of more than a hundred feet. The prevailing color is red, and it is composed altogether of well rounded pebbles of eruptive rocks, cemented with silicious and ferruginous paste.

The Shale occurs interstratified with the sandstone in beds of from a few inches to over a hundred feet in thickness. It is usually soft and of deep blue and black colors, and contains thin bands of black ferruginous limestone and sandstone interstratified. Wherever stone coal abounds it is highly bituminous. Selenite and iron pyrites are of frequent occurrence in it.

As a general rule the rocks of this group are harder and more crystalline in texture on the western than the eastern side of the Plains. In the former region they are also more calcareous in their composition.

EXTENT AND THICKNESS.

Commencing towards the east we find the rocks of the Upper Carboniferous Group well exhibited in the western portions of Iowa, Missouri, and Arkansas, through various portions of the Cherokee, Choctaw, and Chickasaw Territories, and in Eastern and Southeastern Texas. Near the western line of Arkansas they exhibit a vertical development of about two thousand feet, forming here the Ozark Mountains. Thence they are traced almost continuously to Fort Gibson and Fort Washita, being interrupted in the last mentioned direction at two points only, one by a narrow strip of country occupied by strata of older date, and the other by the granitic protrusion already mentioned. At Fort Washita they disappear beneath the Cretaceous strata, but are exposed by denudation at several points between this point and the Upper Cross Timbers of Texas.

Directly west of the Cross Timbers the rocks of the Coal Measures are again met with, and thence extend uninterruptedly as far as the Clear Fork of the Brazos River, or about fifty miles west of Fort Belknap, where they appear in gently-rounded hills and ridges, and exhibit, by their exposed edges, a thickness of upwards of two thousand feet. A few miles west of this they disappear beneath the Cretaceous strata of the Plains, and are not again encountered in that direction until we approach the eastern base of the Rocky Mountains.

Farther south they are known to occur on both sides of the Rio Brazos for the distance of nearly a hundred miles; on the San Saba River, between Forts Mason and McKavett; and also near Fort McIntosh, on the Rio Grande.

Along the route traveled by your Expedition between Victoria and San Antonio heavy beds of coarse quartzose sandstone and conglomerate, agreeing lithologically in all respects with those of the Coal Measures farther north, were encountered. (*Vide Journal.*) These rest unconformably beneath the strata of the Cretaceous System, and are known to contain in several localities beds of iron ore. They have been traced, as I am informed, many miles both north and south of the point where they were encountered by myself, and fifty miles south of San Antonio, on a stream known as the San Miguel River, contain workable seams of bituminous coal. Considering these, therefore, as also belonging to the upper division of the Carboniferous System, they would seem to indicate for the rocks of this group a continuous line of outcrop from Fort Belknap south as far as Fort McIntosh.

Towards the west these rocks exhibit a vertical development of about three thousand feet, and are observed cropping out extensively on both sides of the Rio Grande. Near the sources of Delaware Creek they are seen to emerge from beneath the Lower Cretaceous strata of the Plains, and soon after attain, in the Guadalupe Mountains, an elevation of about three thousand feet Immediately west of this they are partially concealed by strata of the Cretaceous Period, but at the distance of fifteen or twenty miles again appear, and thence westward constitute, with the exception of a few igneous protrusions hereafter to be described, the only rocks met with until we arrive at the western base of the Sacramento Mountains, where they are interrupted by an igneous valley (Valley of the Salt Lakes) from thirty to forty miles in width. Upon the northern side of this valley they are again well exposed in the mountains on both sides of the Jornado del Muerto, as well as at several points between the Rio Grande and Membres Valley.

North of Dona Ana I have succeeded in tracing these rocks continuously throughout the entire length of the region known as the Jornado del Muerto. I have also ascertained their existence at several points between the northern extremity of that plain and Albuquerque. Near Albuquerque they were encountered by Mr. Marcon; Lieut. Simpson met with them in latitude 36 degrees 12 minutes, longitude 108 degrees 52 minutes; Lieut. Abert in latitude 37 degrees 15 minutes, longitude 104 degrees 35 minutes; while still farther north they are mentioned as occurring along the different routes explored by Emory, Fremont, Parker, and Stansbury. Their north and south range upon this portion of the continent is therefore coextensive with that of the same group upon the eastern side of the Plains

In the mountains forming the eastern boundary of the Jornado del Muerto the exposed edges of these strata show a thickness of over two thousand feet. Near the southern extremity of the Sacramento Mountains they are exposed vertically to the thickness of about eight hundred feet. At the Sierra Alto the thickness of their upheaved edges was estimated approximately at about two thousand five hundred feet; while still farther east, along the western face of the Guadalupe Mountains, they are exhibited in a single vertical section to the thickness of near three thousand feet.

LOCAL DIFFERENCES.

In the State of Arkansas the rocks of this group consist of coarse and fine grained quartzose sandstone, with intercalations of thin bedded, dark colored, compact limestone and bituminous shale. The sandstone greatly predominates over the limestone, and is mostly hard, ferruginous, and often easily separated into smooth flat layers. The layers are often highly ripple-marked.

At Fort Belknap the sandstone is in many places soft and highly fissile. Its position is there seen to be below that of the limestone. The latter is hard and highly crystalline, and occurs in layers both massive and thin

bedded. Conglomerate in beds nearly a hundred feet thick occur in this neighborhood. The same rock is also found fifty or sixty miles farther east.

On the Clear Fork of the Brazos River the calcareous rocks also occupy a superior position, and in general thickness, at least as far as the layers in that vicinity are exposed, greatly exceed that of the sandstone. They are mostly compact, thin bedded, and of a light gray color. The sandstone is coarse grained, of moderate hardness, and occurs in massive layers.

Between Victoria and San Antonio the rocks of this group consist mostly of coarse ferruginous sandstone, grits, and conglomerate. The sandstone varies greatly in hardness, and is often of a deep red or brown color. On the San Saba it is granulate and gray.

In the Guadalupe Mountains the calcareous beds are exposed to the thickness of about fifteen hundred feet, and are found occupying positions both above and below the sandstone. The upper beds are mostly white, massive, and highly crystalline, often passing into calcareous spar, while those towards the base are thin bedded, compact, and of a dark blue or black color. The sandstone is both coarse and fine grained, of different degrees of hardness, and usually of a light yellow color. Near its base it is interstratified with thick bands of dark colored shale.

In proportion as we travel west of the Guadalupe Mountains the sandstone appears to gradually thin out, while the limestone becomes proportionably developed. In the upheaval around the Sierra Alto the former is still found occupying a middle position, but does not there exceed in thickness four or five hundred feet. In that locality the limestone, except where in contact with the igneous rocks, is hard, highly crystalline, and of light blue and gray colors.

In the mountains upon the eastern side of the Jornado del Muerto the limestone is both thick and thin bedded, and varies in color from light gray to blue and black. When struck with the hammer it often emits a sulphurous odor. The exposed layers of sandstone do not there exceed in thickness one or two hundred feet. In the mountains upon the western side of that plain, however, it is exposed to the thickness of five or six hundred feet. In this locality it is coarse grained, passing into millstone grit, and contains thick seams of soft dark colored shale.

PHYSICAL CHARACTER.

In general physical character the rocks of the Coal Measures differ in a remarkable manner from those of the Cretaceous System. Wherever they occur they exhibit strong evidences of subterraneous disturbance as well as of subsequent denudation, and therefore usually impart to the country a rough and broken character, accompanied with great variety and picturesque beauty of scenery. Upon the eastern side of the Plains they are seen rising in abrupt or gently sloping ridges to the height of one or two thou-

sand feet, with broad, undulating valleys intervening; while towards the west they constitute, as already intimated, some of the loftiest summits of the Rocky Mountains.

From the general character of their dislocations the causes producing them would seem to have operated in a much more sudden and violent manner towards the east than towards the west. In the Ozark range of mountains the strata are often seen violently twisted as well as fractured, and dipping in different directions at high angles, while the ridges of greatest elevation pursue a very irregular course, often approaching or blending with each other, and are interrupted at frequent intervals by broad and deep valleys.

Towards the west, on the contrary, the mountains exhibit a remarkable uniformity in general character, and are grouped together in nearly parallel ranges, while the lines of dislocation are exceedingly well defined, and are traced continuously north and south over areas hundreds of miles in extent. The uplifted layers, too, are usually found dipping uniformly, and often at comparatively moderate angles either towards the east or the west, and are, at least as far as my own observations have extended, much less marked by local flexures or violent contortions than upon the eastern side of the Plains. The causes producing the dislocations in this direction would appear, therefore, to have operated in a much more gradual and uniform manner than towards the east, and to have extended at the same period north and south over extensive districts of country.

The great extent to which the rocks of this formation have yielded to denudation is well exhibited in the Guadalupe Mountains near their southern extremity. The materials derived from these mountains are, as already remarked, spread over the Plains towards the east for the distance of a hundred and fifty miles, and fully attest by their abundance the great amount of solid strata thus removed. Farther west the evidences of extensive denudation are equally well exhibited. In some of the canyons of the Organ Mountains beds many feet in thickness appear to have yielded in this manner, the materials derived from these sources being found profusely scattered over the adjacent valleys, sometimes twenty or thirty miles from their original position.

ECONOMICAL GEOLOGY.

MATERIALS FOR CONSTRUCTION.

Wherever these rocks occur there can be no want of excellent building materials. From their great hardness and durability they are exceedingly well adapted for large public edifices, as well as for roads, bridges, and other works of internal improvement. Should the contemplated railroad from the Mississippi Valley to the Pacific Ocean, therefore, ever be constructed, they would furnish over a large portion of the route the very best of rich materials for that purpose.

By burning, an excellent quality of quicklime for mortar can almost always be obtained from the limestone. Some of the dark varieties of limestone would also furnish good hydraulic cement.

COAL.

Among the useful minerals hitherto discovered in this formation, decidedly the most important, as well as the most extensively distributed, is coal. This valuable substance, so inseparably connected with the prosperity of many of the States of the Union, occurs in the greatest abundance throughout various portions of Arkansas, Texas, and the adjacent Cherokee, Choctaw, and Chickasaw Territories. In the State of Arkansas the coal seams, so far as yet ascertained, are from a few inches to eight or ten feet thick, and are seen reposing successively one above another, with their intervening shales, sandstones, and grits, in a manner very similar to those of Missouri, Illinois, and Kentucky. They occupy by far the greater portion of the western half of that State, and are observed cropping out extensively along the Arkansas River between Little Rock and Fort Smith, as well as much farther south. Near Fort Smith several seams of this mineral have been discovered; one of them, eight feet in thickness, has been successfully worked for several years past, and is capable of yielding annually thousands of tons of the very best quality of fuel. The coal obtained from the neighborhood is light, highly bituminous, possesses an uneven fracture, and burns with a brisk flame, leaving but little residue and no cinder. In the direction of Little Rock it assumes more the character of cannel coal.

From Fort Smith coal deposits are traced, by means of numerous outcrops, to within a few miles of Fort Gibson, in the Cherokee Nation, and in a southwesterly direction as far as Fort Belknap, in Texas; thence southward they are found to occur on both sides of the Brazos River for the distance of seventy or eighty miles; also on the San Miguel River, fifty miles south of San Antonio, and near Fort McIntosh, on the Rio Grande.

Localities for Coal.

In treating of the different localities in Texas and the adjacent Indian Territories in which workable seams of coal have been discovered, I shall confine myself chiefly to such ones as are most important within the limits of the region explored by myself. It is important, however, to bear in mind that this region composes only a portion of the vast coal district of the southwest, and that nearly all the discoveries of coal hitherto made within its borders are purely accidental, as no systematic effort has ever been made for the development of this branch of its mineral wealth.

Bituminous coal of very fair quality has been ascertained to exist in several localities between Fort Smith and Fort Gibson, in the Cherokee

Nation. The seams, however, are for the most part poorly exposed, and appear to have been but little worked. Their thickness, therefore, can not be very accurately determined. The coal is both underlaid and overlaid by thick beds of black bituminous shale, containing iron pyrites and thin bands of black ferruginous limestone. In the neighboring sandstones sigillaria and calamites have been discovered in the greatest abundance. The impressions of the leaves of coal vegetables are also found in the shale.

In two localities on the Pateau River, one eight and the other about fourteen miles southwest of Fort Smith, seams from three to six feet in thick ness have been discovered. The coal is light, brittle, breaking with an uneven fracture, and highly bituminous. It contains but little sulphur or other impurities, and burns with a clear, bright flame, leaving but little ashes and few cinders. The associated shales are over sixty feet in thickness, and contain thin bands of laminated sandstone and nodules of ironstone, the whole being overlaid by thin bedded quartzose sandstone, containing calamites and other fossils, and often thickly ripple-marked.

On Bayou Zeal, a small tributary of the Pateau River, two seams, one six inches and the other about six feet in thickness, are exposed. The coal is of excellent quality, and very closely resembles that in the neighborhood of Fort Smith. Neither of these seams have been much worked.

At the Narrows, on the Fort Washita road, a few miles west of the last mentioned locality, a seam one foot in thickness is exposed near the bottom of a deep ravine. The coal is hard, compact, and burns with a brisk flame. The associated shale is only three or four feet in thickness, and is underlaid by coarse quartzose sandstone and grit. This seam appears to occupy a position much lower in the series than those last described. The coal is also of inferior quality, and in some places contains much slate.

On Gaines Creek, a tributary of the Canadian River, bituminous coal is found cropping out in several places. The coal is represented to be of very good quality. Thickness of seams unknown. Coal is also found on Coal Creek, a small tributary of the last.

Near the Fort Washita road, six miles west of Gaines Creek, a seam eighteen inches in thickness is found cropping out from beneath heavy bedded quartzose sandstone. The coal has been employed by the blacksmiths in the neighborhood, who pronounce it of excellent quality. Six miles farther west another exposure of coal occurs. The seams vary in thickness from eighteen inches to two feet. The coal is heavy, compact, and breaks with a square fracture.

Near the Fort Washita road, about eight miles west of the residence of Mr. Blackburne, I am informed by that gentleman, a seam of bituminous coal over ten feet in thickness has been discovered. The coal is represented to be light, brittle, and of excellent quality, and is overlaid by shale and thin bedded quartzose sandstone. Near this locality occurs an extensive

exposure of heavy bedded, light gray, cherty limestone, containing goniatites and encranite stems in great abundance.

Twelve miles east of Boggy Depot, in the Chickasaw Nation, a seam from one to two feet in thickness has been discovered. Quality of coal unknown.

At a point about twenty miles north of Boggy Depot several seams are found cropping out. They vary in thickness, as I am informed, from two to seven feet, and present at the side of a hill in such a manner as to be very easily worked. The coal is bituminous, and represented by those who have tried it to be of good quality. No specimens from this locality have been examined by myself.

Between Fort Washita and the Cross Timbers of Texas the Coal Measures are, as already remarked, generally concealed by strata of the Cretaceous System. They have been, however, exposed at a number of localities by denudation, and at three points workable seams of coal have been discovered.

The first of these localities occur about eight miles east of Preston, on Red River. Here the coal is exposed near the bed of a small creek, and exhibits a thickness of several feet. I am informed by Mr. Tyson, who discovered this coal, that it is of excellent quality.

The second locality is about twelve miles, and the third, near the residence of Mr. McCarty, about thirty-five miles west of Preston. The coal from both of these localities is, as I am informed, of very fair quality, and well adapted for manufacturing purposes.

Bituminous coal has been discovered near Gainesville, Texas. Thickness and character unknown.

In the vicinity of Fort Belknap coal is found cropping out extensively in no less than four distinct localities. The seams—of which there are several—usually present in such a manner as to be very easily worked, and from their great thickness are capable of affording with comparatively little labor an inexhaustible supply of excellent mineral fuel.

This coal is likewise bituminous, but differs somewhat in character from that occurring farther east. When first taken from the seam it is usually hard, compact, and of a pitch-like luster, soiling the fingers but very little, and breaks with a smooth square fracture, but upon exposure to the weather becomes soft, of an iron rust color, and separates into very thin laminæ. When heated it softens and swells a great deal, and burns with a reddish flame and much smoke, leaving a good deal of ashes and cinders. The seams sometimes contain nodules and thin bands of black limestone and bisulphuret of iron (*Iron Pyrites*). These can, however, be very readily distinguished and separated from the coal in the mines, and need, therefore, interfere but very slightly with its value.

Section No. VI is taken, about one mile north of the Fort, from the side of a deep ravine, which extends into the high bluffs forming at this point the eastern boundary of the valley of the Rio Brazos, and exhibits an ex-

posure about two hundred feet in length, of coal, shale, and sandstone. The coal occupies the base of the section, and presents a thickness above the bed of the ravine of about ten feet. How far it extends downward is not known, as no artificial excavations have been made below the bed of the ravine, but from the fact of coal being also exposed in the floor of the ravine, which is quite uneven, it is presumable that it extends downward several feet.

The seam contains nodules and thin bands of black ferruginous limestone and bisulphuret of iron. These are sometimes crowded with fossils, principally of the following species: *Pleurotomaria carbonaria*, *P. ornata*, *Myalina subquadrata*, etc.

The overlying shale and sandstone are in places also highly fossiliferous. The former is about five feet in thickness, and contains selenite and nodules and thin seams of ironstone. The sandstone is soft, thinly laminated, the laminæ being about one-twentieth of an inch in thickness and of a light color.

In the other localities in this vicinity the seams are of uniform thickness, but do not differ in general character from those above described.

Large specimens of bituminous coal were obtained from the bed of the Brazos River, ten miles southeast of the Fort. Two miles south of this a thin seam of the same mineral has been discovered.

On the Brazos River, seventy miles below Fort Belknap, as I am informed by Major Neighbors, coal crops out extensively. It is represented as bituminous and of good quality. Coal is also reported to occur at several points between this and San Antonio. I have been unable to obtain specimens from any of these localities.

As already remarked, coal has been discovered on the San Miguel River, fifty miles south of San Antonio. From this locality it has been hauled to San Antonio, and there employed by the blacksmiths, who pronounce it of moderately fair quality. By a gentleman engaged in working the seams I have been furnished with the following section of this locality:

1. Soft bluish-black bituminous shale.
2. Black bituminous coal, 2 feet thick.
3. Shale of the same character as above.
4. Bituminous coal, 18 inches thick.
5. Shale.
6. Bituminous coal, 20 inches thick.

These are both underlaid and overlaid by quartzose sandstone.

The coal on the Rio Grande* is reported, by several army officers stationed in that vicinity, to occur in beds of great thickness, and will no doubt hereafter prove of inestimable value. It is bituminous, and is found associated with shales, sandstones, and grits, the same as in other portions of Texas.

* The Coal Deposits on the Rio Grande were published in the "Report to the Rio Grande Land Company" as early as the year 1834.

On the Nueces River, ten miles west of Fort Inge, a seam of bituminous coal several feet in thickness has been discovered. The coal has been employed by the blacksmiths at the Fort, and found to be of good quality. This deposit is probably cretaceous.

No mineral coal has heretofore been discovered in any portion of the region examined by myself west of the Guadalupe Mountains. From the general character of the strata, however, I feel satisfied that more thorough explorations in that direction will succeed in developing the existence of this mineral over a very large extent of territory. Strong evidences of the existence of coal were discovered by myself in several localities in Western Texas and New Mexico.

METALLIC ORES.

Iron is found abundantly distributed through the rocks of the Coal Measures in various portions of Arkansas and the adjacent Indian Territories; also in Eastern Texas. Among the different ores of that metal hitherto discovered in this region, the most abundant are the Brown Hematite, Magnetic Oxide, and Bisulphuret, or *Iron Pyrites.*

Copper, in the form of black oxide and sulphuret, or Copper Pyrites, has been discovered in abundance in the Chickasaw Nation and in several localities in Western Arkansas.

Lead, in the form of sulphuret, or common galena, occurs abundantly in Western Arkansas. It has also been found in the Choctaw and Cherokee Territories.

The ores of other metals have been discovered in connection with these rocks in Western Arkansas and the neighboring Indian Territories, but inasmuch as they do not occur near any of the proposed railroad routes, it has not been thought advisable to mention them.

SPRINGS.

The region occupied by this formation is usually much better watered than that of the Cretaceous System. This, towards the west, is owing mainly to the greater elevation of the exposed edges of the strata, by which means they are made to receive a much larger proportion of rain than usually falls upon the Plains, while the rocks themselves are generally of such a nature as to absorb water readily, which, following the general dip of the strata, may gush out anywhere at lower levels in the form of springs; hence they are abundantly met with near the base of many of the mountains of Western Texas and New Mexico, while upon the Plains to the east but little water is found. In the region bordering the eastern side of the Plains, the rocks of this group being still more favorably situated with regard to atmospheric moisture, the surface is abundantly enlivened with springs and brooks, and there is no deficiency of good water.

CHAPTER V.

2. MOUNTAIN LIMESTONE, OR LOWER CARBONIFEROUS.

The Mountain Limestone, or Inferior Carboniferous Group, rests immediately beneath the Coal Measures, and is composed principally of limestone, quartzose sandstone, and argillaceous shale. Of these the limestone greatly predominates, constituting fully five-sixths of the entire mass of the formation, and is traversed by the sandstone and shale in layers of variable thickness. It occurs both massive and thin bedded, the layers being in some localities over a hundred feet in thickness, while in others they do not exceed in this respect a few inches. It is usually hard and highly crystalline, and sometimes contains irregular masses of pure calc-spar. Occasionally it is homogeneous in texture, and breaks with a smooth conchoidal fracture. The predominating colors of this rock are light gray and blue, from which they pass into brown and black. In a few instances it is white. In some localities the seams are largely intermixed with chert, and are occasionally, more especially towards the west, traversed by veins of quartz, calc and fluor spar.

The Sandstone varies considerably in character. Most generally, however, it is hard, and composed of coarse quartzose grains. In some places it is soft, highly ferruginous, and rapidly disintegrating Its prevailing colors are light gray and yellow, from which it often graduates into red and brown. Occasionally it is white and saccharoidal. The different beds very seldom exceed a hundred and fifty or two hundred feet in thickness, and are usually well defined, there being an abrupt transition from the sandstone into the limestone.

The Shale sometimes occurs in seams seventy or eighty feet in thickness. It is mostly soft, of a dark blue or black color, and contains thin seams of dark limestone. In places it is highly ferruginous, and is often interspersed with nodules of brown iron ore. As in the preceding group, these rocks are generally harder and more crystalline towards the west than towards the east. In the former situation they are also sometimes found in a highly metamorphosed condition, and often emit a sulphurous odor when struck with a hammer.

EXTENT AND THICKNESS.

Commencing towards the east, we find the rocks of this group well developed near the western borders of Arkansas, where they exhibit by their exposed edges a general thickness (estimated approximately) of about two thousand feet. In Washington county, in that State, they form the

Boston and several others of the loftier summits of the Ozark range of mountains, and there constitute a portion of the principal axis or line of greatest elevation between the Illinois and White Rivers. Immediately west and southwest of this they disappear beneath the arenaceous beds of the Coal Measures, but afterwards reappear at several points in the Cherokee and Choctaw Territories. In the latter Territory, about 100 miles southwest of Fort Smith, they are well exposed in a low ridge, which extends irregularly across the country for many miles in a southeasterly direction. Beyond this they are again seen to dip beneath the rocks of the Upper Carboniferous Group, and are no more met with in that direction during the remainder of the distance to Fort Belknap and the Clear Fork of the Brazos River.

On the San Saba River, at a point about midway between Fort Mason and Fort McKavett, the rocks of this group are seen cropping out extensively from beneath thick strata of the Cretaceous Period. At this locality the thickness of their exposed edges was estimated by myself at about two thousand five hundred feet. (*Vide Journal.*) The same outcrop is described by Roemer, who succeeded in tracing it many miles east of the point (on the San Antonio road) where it was encountered by myself.

Towards the west, strata belonging to this division of the Carboniferous System has been met with in the Organ and Fra Cristoval Mountains. In the Organ Mountains their exposed edges are exhibited in some places to the thickness of about three thousand feet. Commencing about twenty miles north of El Paso, they are traced in low hills and ridges along the western base of the igneous protrusions, of which these mountains are there mainly composed, to a point nearly due east of Fort Fillmore. Here they suddenly attain an elevation of about three thousand feet, but immediately afterwards descend, and thence northward appear at a few points only along the western base of the mountains until we arrive in the neighborhood of the San Augustine Pass, about fifteen miles east of Dona Ana, where they are exposed to the thickness of seven or eight hundred feet. A little north of this they again attain an elevation of several thousand feet, and from that point constitute, with the exception of the overlying Coal Measures already mentioned and an interrupted chain of igneous hills, the entire mass of the Organ Mountains as far north as the northern extremity of the Jornado del Muerto. Upon the western side of this plain they are again met with in the Fra Cristoval Mountain. In this mountain the thickness of their exposed edges was estimated approximately at about two thousand feet.

On both sides of the Plains north of the region examined by myself the rocks of this group have been abundantly encountered by other explorers. Towards the east they are mentioned by D. D. Owen as occurring along the western borders of Iowa and Missouri; while in the opposite direction they have been encountered by Mr. Marcon near Albuquerque, and by others at various points in the Rocky Mountains much farther north.

LOCAL DIFFERENCES.

In the western portion of Arkansas the calcareous rocks of this group occur mostly in massive beds of great purity. Their color varies from light gray to blue and brown. They are usually highly crystalline, and sometimes contain irregular masses of calc-spar. Occasionally they are homogeneous in texture, breaking with a smooth conchoidal fracture, and of a bright fawn color.

In the Choctaw Territory, a hundred miles southeast of Fort Smith, the limestone is hard, compact, and of a light blue or drab color. It is there largely intermixed with chert, and as far as exposed contains no layers of sandstone.

On the Upper San Saba River it is thin bedded, of a dull gray color, and more or less granular. The sandstone is hard, coarse grained, and highly ferruginous, sometimes passing into silicious iron ore, and in color varies from deep brown to red and black. In places it is highly metamorphosed.

In the Organ Mountains the limestone is hard, highly crystalline, and occurs in layers of variable thickness, being in some places massive and in others thinly laminated. Its prevailing color is blue, from which it passes into various shades of gray, brown, and black. The sandstone is both coarse and fine grained, and usually of a light yellow color. These rocks are here traversed by tortuous veins of quartz, calc and fluor spar, and often exhibit a highly metamorphosed appearance.

In the Fra Cristoval Mountain these rocks do not differ in general character from what is observed in the Organ Mountains.

PHYSICAL CHARACTER.

Like that of the preceding group, the country occupied by the Lower Carboniferous rocks exhibits strong evidence of subterraneous disturbance, as well as of subsequent denudation, and is characterized by a rough and broken surface, lofty mountains, rugged precipices, and great variety and beauty of scenery. Wherever favorably situated with regard to climate, as in Western Arkansas, it is well supplied by innumerable springs with the best of water, covered with highly productive soil, and it well affords every inducement for the agriculturist.

ECONOMICAL GEOLOGY.

MATERIALS FOR CONSTRUCTION.

These rocks furnish excellent building materials. The limestone and sandstone are both hard and durable, and are, therefore, well adapted for

edifices, both of a public and private character. For bridges, roads, and other works of internal improvement they likewise furnish the most approved materials. By burning, a good quicklime for mortar can almost always be obtained.

METALLIC ORES.

Of the different metallic ores occurring in this formation, the most important are those of silver, lead, and iron.

Silver, associated with sulphur and lead in the form of argentiferous galena, is found along the western base of the Organ Mountains, in New Mexico. The ore is there exposed at the surface in veins, all of which are contiguous to eruptive rocks, and occur, at least as far as my own examinations have extended, in thin bedded, hard, compact, dark blue and black crystalline limestone. The veins are all nearly vertical, and preserve a highly tortuous course, their direction being in some places north and south, and in others inclined towards the east and west. Their thickness, including matrix and all, varies from five to ten feet. The ore is often mixed with a small percentage of iron and titanium, and sometimes contains traces of copper and other metals. When pure it yields from four to six ounces of silver to the hundred pounds. Associated with it as a matrix we have calc and fluor spar. Of these two the former greatly predominates, and is for the most part highly discolored with black and red oxide of iron, while the fluor spar occurs mostly in semi-transparent masses, and is of a beautiful green color.

About fifteen miles east of Dona Ana two of these veins are well exhibited. One is situated near the base of the exposed limestone, which is here strongly upheaved, dipping towards the west at an angle of about 80 degrees, and the other near its summit. The first is about eight feet in thickness, and has at one point been partially worked by means of a shaft sunk to the depth of ten feet. The metalliferous portion occupies fully one-third of the entire thickness of the vein, and occurs in such a manner as to be very easily separated from the gangue. This vein, at the point examined by myself, has a W. N. W. bearing, and is traced, as I am informed, for the distance of several hundred yards on both sides of the shaft. From some cause or other it has not been worked for several years past, although, from the character and thickness of the ore, it would doubtless, if properly managed, prove highly profitable. The second vein is about ten feet in thickness, and is at present worked by Mr. Stephenson, who has sunk a shaft in it to the depth of near thirty feet. The ore occurs in a solid sheet from eighteen inches to two feet in thickness, and is also very easily separated from the gangue. After its extraction it is conveyed upon the backs of mules to the place of smelting, a distance of about sixteen miles, and in spite of the great disadvantages attending its present mode of working, the

silver being only partially separated from the lead, and the latter, for want of a market, thrown aside as refuse, yields, as I am informed, a very handsome profit. The direction of this vein is nearly north and south.

The position of these two veins, as well as the character of the neighboring rocks, are shown in the accompanying Section No. ——

About one mile north of Mr. Stephenson's mine, near the San Augustine Pass, several other veins are exposed at the surface. None of them, however, appear to have been much worked, although, from the character and thickness of the ore, they could no doubt be made highly profitable.

Silver is also found in connection with lead in Arkansas. It there, likewise, occurs in the vicinity of eruptive rocks.

Lead.—Besides the argentiferous galena above mentioned, lead has been found in several localities in Washington county, Arkansas. It there occurs mostly in the form of sulphuret. Specimens of this ore from that region were tested by myself, and found to yield near eighty per cent of lead. The same metal has been found in connection with the Mountain Limestone in the Cherokee Territory.

Iron, in the form of oxide, is very generally distributed throughout the rocks of this formation, and furnishes the principal portion of their coloring matter. This metal has been found in workable quantities in several portions of Western Arkansas and the adjacent Indian Territories.

LOWER SILURIAN SYSTEM.

Strata belonging to the Devonian and Upper Silurian Periods have not been encountered by myself in any portion of the region under consideration. Others, however, unequivocally Lower Silurian in their character, have been met with along the western base of the El Paso Mountains, a few miles north of Fort Bliss. These rocks are there found resting in immediate contact with eruptive rocks, and consist of upheaved and highly contorted strata of hard, compact, light gray and blue crystalline limestone. They are exposed only at intervals; in some places exhibit a thickness of about three hundred feet, and are traced in a northerly direction for the distance of ten or eleven miles. Near their junction with the igneous rocks they are highly metamorphosed, and exhibit no traces of organic remains, but at a little distance are crowded with well preserved fossils, among which I have succeeded in recognizing the following well known species: *Orthis testudinaria*, etc.

At several points along the western base of the Organ Mountains farther north, strata of the same lithological character were observed cropping out from beneath the fossiliferous beds of the Lower Carboniferous Group. No fossils, however, were detected in any of them.

CHAPTER VI.

ERUPTIVE ROCKS.

Most of the eruptive rocks encountered by myself in Texas and New Mexico are described in detail in the Journal and accompanying report upon the Jornado del Muerto. I shall, therefore, in this place only notice those of the Limpea Mountains, and such others as were examined during my former trip to the sources of Red River. The general distribution of this class of rocks in the region under consideration will be more particularly noticed when I come to speak of mountain ranges.

Eruptive Rocks of the Limpea Mountains.—These, as far as examined by myself, consist mostly of claystone and feldspar porphyries and dark colored basalt. The porphyries are hard, compact, and of purple, red, brown, and gray colors. Their crystals are usually well defined, and consist for the most part of labradorite, quartz, and feldspar. Those composed of labradorite are by far the most abundant, and usually exhibit in great perfection the characteristic change of colors of that mineral. The basalt is only observed near the northern base of the mountains. In some places it is hard and very compact, while in others it is soft or more or less vesicular, sometimes passing into vesicular lava. All these rocks appear to be yielding rapidly to the weather, and are traversed in almost every direction by deep fissures or canyons, some of which are many miles in length. Externally they are of reddish brown and black colors, and not unfrequently their weathered surfaces present a highly glazed or polished appearance.

Eruptive Rocks of the Witchita Mountains.—The rocks of the Witchita Mountains consist of hard, compact granite and porphyry, with occasional veins of greenstone, hornblende, and cellular and compact quartz. The granite is far more abundant than the porphyry, and composes the great mass of the formation. It is usually fine textured, of a deep red color, and contains a great predominance of feldspar and a deficiency of mica, the latter mineral being in many instances almost entirely absent. Not unfrequently the rock passes into nearly pure feldspar. Externally it is of deep brown, yellow, or red colors, and owing to the great number of joints and master joints by which it is traversed, presents somewhat of a cuboidal structure.

The porphyry is confined almost exclusively to the eastern extremity of the mountains, where it is exhibited in gently rounded hills and ridges from three to five hundred feet high. It is also of a deep red color, but is usually much softer than the granite. Its crystals are mostly small and composed of flesh-colored feldspar. The veins of greenstone, hornblende, and quartz are sometimes many feet in width, and traverse the mountains in almost every

direction. Those of quartz are apparently much more abundant in the porphyry than in the granite. Near Cache Creek several of them are seen traversing the mountains from top to bottom. The quartz in that situation is highly ferruginous, often exhibiting distinct crystals of bisulphuret of iron, and contains small irregular cavities partially filled with liquid naptha. In Otter Creek, a small affluent of Red River, having its sources in these mountains, two specimens of bluish yellow quartz, each containing a small particle of gold, were found. Black ferruginous sand has also been discovered in great abundance in several of the streams flowing from these mountains.

Igneous Protrusion near Fort Washita.—This protrusion has been traced in a northeasterly and southwesterly direction for the distance of about thirty miles, with an average width of about six miles. It consists altogether of coarse porphyritic granite and quartzose rock. The granite is mostly hard, of a reddish color, and contains distinct crystals of feldspar of the flesh colored variety. It is traversed by the quartz in thick veins, which are in some localities quite numerous. This rock is mostly white and very compact. In a few places it is highly discolored with oxide of iron.

MOUNTAIN RANGES.

Eight different ranges of mountains have been examined by myself in Texas and New Mexico. Of these four are composed entirely of eruptive rocks, one partly of eruptive and partly of sedimentary rocks, and three altogether of sedimentary rocks. Those composed entirely of eruptive rocks are the Witchita, Limpea, Hueco, and Membres Mountains. The Organ Mountains consist partly of sedimentary and partly of eruptive rocks, while those altogether sedimentary in their composition are the Guadalupe, the Sacramento, and the Horse Mountains, the last including the Fra Cristoval and Robledo Mountains, both of which are but detached portions of the same range. Although differing remarkably in their general composition, these different ranges possess certain features in common which at once serve to distinguish them from any of the mountains occurring east of the Plains. With the exception of the Witchita range they all have a general north and south bearing, and the parallelism of the lines of eruption or of upheaval are usually exceedingly well marked, the different chains being sometimes traced continuously for hundreds of miles, with the same general curves, and with broad, smooth intervening valleys, open only at their northern and southern extremities. Owing to the great thickness of the quaternary deposits of western Texas and New Mexico, the minor inequalities of the surface of the country are generally obliterated, so that the mountains are usually seen rising abruptly from smooth level or gently ascending plains, while for the same reason many of the igneous protrusions of these regions appear completely isolated that would otherwise be exhibited in continuous chains, their *lower portions* being covered by these deposits.

The mountains composed entirely of sedimentary strata are remarkable for their great general uniformity of character. They occur mostly in continuous ranges, each one of which exhibits usually but a single slope, which is either towards the east or the west, being abruptly terminated in the opposite directions by bold vertical or nearly vertical escarpments, some of which, as for instance those forming the western faces of the Guadalupe and Sacramento Mountains, are nearly three thousand feet in height.

Inasmuch as the ranges composed altogether of sedimentary rocks are fully discussed in the Journal and report upon the Jornado del Muerto, besides being several times referred to in the chapters upon the Carboniferous System, I shall for the present confine myself entirely to such as are composed wholly or partially of eruptive rocks.

WITCHITA MOUNTAINS.

With the exception of those occurring near the eastern extremity of the range, these mountains present a nearly uniform appearance and structure. Composed mostly of fine granite, they rise abruptly from a smooth and nearly level plain, and attain at their highest points an elevation of about nine hundred feet. Many of them are completely isolated, and of an irregular conical shape, while others are grouped together in clusters of eight or ten, and are more or less rounded. At a distance they appear to be smooth, but upon a nearer approach their surfaces are found to be quite rough, and present very much the appearance of loose rocks thrown confusedly together. This range is about seventy miles in length, and varies in width from five to fifteen miles. Its general bearing, as determined by Capt. R. B. Marcy, is about south 60 W.

At the base of these mountains the Marly Clay Formation (Lower Cretaceous) is exhibited in nearly horizontal layers, and presents generally but little evidence of disturbance, while the clays and sandstones have been found in several localities to contain inbedded fragments of rocks in all respects similar to those of the mountains. The period of eruption of these mountains must, therefore, date anterior to that of the deposition of the Lower Cretaceous Strata of the Plains.

LIMPEA MOUNTAINS.

The Limpea range has been only partially examined by myself. As already remarked, it is composed mostly of dark colored porphyry and basalt, and is evidently much more recent in origin than the range last considered, its protrusions occurring after the deposition of the limestone of the Upper Cretaceous group, which is found strongly upheaved against its northern base. These mountains exhibit at their highest points an elevation of about one thousand feet above the level of the surrounding country, and as

far as examined by myself present everywhere a dark and exceedingly rugged appearance. In some instances they are completely isolated, and are seen rising in the form of truncated cones; in others their summits are sharp and jagged, and from their peculiar shape are sometimes compared not very inaptly to a bishop's mitre. Most frequently, however, they are grouped together in short detached ranges, most of which appear to have a general north and south bearing, and are usually marked on all sides by abrupt and in many instances nearly vertical walls, which sometimes exhibit a slightly columnar appearance.

HUECO MOUNTAINS.

Under the name of Hueco Mountains are included all igneous protrusions encountered by the Expedition between the sounthern extremities of the Guadalupe and Sacramento Mountains as well as those described in the Journal as occurring farther north along the western base of the Sacramento Mountains.

This range consists altogether of isolated peaks, the highest of which, the Sierra Alto, is about fifteen hundred feet above the level of the surrounding plain. Towards the south they are generally much more elevated than at the north, and pursue a very irregular course, their general direction being there pretty nearly W. S. W. Near the Sierra Hueco, however, they are seen to bend abruptly towards the north, and are afterwards traced in low hills and ridges for a considerable distance along the western base of the Sacramento Mountains. As far as examined they are, with a single exception (viz., Sierra de los Alamos), composed entirely of fine compact granite, containing a much larger percentage of feldspar than usual, and a deficiency of mica. Around the base of several of them the limestone and sandstone of the Coal Measures are found metamorphosed and strongly upheaved. The protrusion of these mountains must, therefore, have occurred after the close of the Carboniferous Period.

MIMBRES MOUNTAINS.

The Mimbres Mountains form a nearly continuous range, whose general bearing is pretty nearly north and south. As far as examined they appear to attain their greatest elevation at the Picache de los Mimbres, a sharp conical peak situated near their southern extremity, from which point there is a gradual descent towards the north. At the "Picache," the only portion of the range visited by myself, the principal rock was found to be a hard and very compact porphyritic granite, which composed the main axis, with porphyry, quartz, vesicular amygdaloid, and chalcedonic rocks on either side. No sedimentary rocks were anywhere observed in the neighborhood. I am, therefore, unable to form an opinion with regard to the relative age of these mountains.

ORGAN MOUNTAINS.

This range, as already remarked, is composed partly of eruptive and partly of sedimentary rocks. The eruptive rocks consist mostly of hard, compact, red and gray porphyritic granite and red porphyry. Those towards the south are seen rising in sharp jagged peaks to the height of near three thousand feet, and with some local exceptions constitute all that portion of the range lying between El Paso and the San Augustine Pass. Immediately north of this pass the eruptive rocks are seen to descend rapidly, and at the distance of a few miles farther north are exhibited only in low detached hills, their place in the mountains becoming occupied by upheaved strata of the Carboniferous System, which last soon attain an elevation of about three thousand feet, and thence northward constitute the principal portion of the Organ range until we arrive at the northern extremity of the Jornado del Muerto, beyond which point my examinations have not extended.

Wherever the sedimentary strata prevail the mountains exhibit but a single slope, which is uniformly towards the west, being abruptly terminated in the opposite direction by lofty escarpments, many of which are nearly vertical. So far as ascertained, the most recent strata elevated by these mountains are those of the Coal Measures. The period of eruption and of upheaval must, therefore, have occurred subsequent to the deposition of these strata.

VOLCANIC RANGE.

Besides the mountains above described, a volcanic range of much more recent origin has been traced for several hundred miles along the Rio Grande. The general direction of this range appears to be pretty nearly north and south. I have myself encountered it at several points between El Paso and the Fra Cristoval Mountain. By Mr. Marcon and others it is mentioned as occurring as far north as Albuquerque and Santa Fe, while Mr. Thompson, a member of our own party, informs me that he has traced it in a southerly direction to the Laguna Patos, nearly a hundred miles south of El Paso. The range, as far as examined by myself, is formed altogether of isolated conical hills, which vary in height from three to six hundred feet, and are composed entirely of dark greenish compact basalt and vesicular lava. From each of these cones streams of dark colored vesicular lava, varying in width from a fourth to one or two miles, and from thirty to seventy feet in thickness, are seen to have issued. Several of these cones and lava streams are described in detail in the Journal and report upon the Jornado del Muerto. The lava appears to have undergone but little alteration since the period of eruption, its upper surface being black, highly vesicular, and totally devoid of vegetation, and from the fact of its being usually found resting above the drift is evidently of more recent origin than the latter.

TAINS.

PART SECOND.

JOURNAL OF GEOLOGICAL OBSERVATIONS

ALONG THE ROUTES TRAVELED BY THE EXPEDITION
BETWEEN INDIANOLA, TEXAS, AND THE VALLEY OF THE MIMBRES, NEW MEXICO.

BY GEO. G. SHUMARD.

CHAPTER I.

FROM INDIANOLA TO SAN ANTONIO DE BEXAR.

As the scientific division of the Expedition was fully organized previous to our leaving Indianola, it was thought advisable to commence the geological investigations at that point.

The country in the vicinity of Indianola is for the most part flat, and but little elevated above the adjacent bay of Matagorda. It is traversed in different directions by long, narrow lagoons, whose depths vary from a few inches to fifty feet. These are apparently diminishing in size, while the dry beds of others, often containing thick accumulations of *Ostrea* and other marine shells of existing species, and the low, flat character of the surface generally, proclaim this region to have been but recently recovered from the domain of the Ocean.

The Geological Formation here consists of alluvial deposits of tough calcareous clay, of light blue and red colors, and fine yellow calcareo-silicious sand. The sand is a more recent deposit than the clay, and is arranged chiefly along the coast in nearly parallel ridges, from five to twenty feet in height, thus constituting a kind of natural levee. As these ridges coincide with the various indentations of the coast, and are largely composed of finely comminuted shells, they are doubtless the result of the conjoint action of the waves and wind; the former throwing the materials up, the latter transporting them inland.

We left Indianola on the 4th of April, the general direction to be pursued from this point to San Antonio de Bexar being nearly northwest.

During the first day's march we traveled over gently undulating prairie, composed of alluvial deposits of tenacious clay and dark silicious sand; the

former assuming a variety of colors—black, brown, red, blue, and light yellow, — and containing small white particles of carbonate of lime. The darker varieties of clay greatly predominate over the others, and are always observed nearest the surface. The sand is only occasionally seen, and does not attain any considerable thickness. It is for the most part coarse, highly ferruginous, and contains pebbles of metamorphic rocks scattered through it, and is sometimes loosely cemented with ferruginous and calcareous matter.

The surface is often characterized by numerous small ridges, from two to three feet high, familiarly known as "Hog Wallows."

Soil a deep vegetable mould, highly productive; sub-soil generally calcareo-argillaceous, sometimes arenaceous.

Distance traveled, 25 miles.

April 5.—For the first fifteen miles we continued to travel over deposits of the same character as noted yesterday. Afterward the formation became much more arenaceous, consisting chiefly of coarse yellow quartzose sand, with pebbles and small boulders of silicious rocks disseminated through it. Surface gently undulating, and covered, as far as Victoria, with dark, rich, arable soil.

At Victoria we crossed the Guadalupe River, which is here about fifty feet wide, flowing between high bluff banks. Here I saw, for the first time since leaving Indianola, strata of older date than those of the Quaternary Period. They consist of laminated layers of soft, crumbling, reddish quartzose sandstone, with rounded silicious pebbles embedded, which are sometimes so abundant as to form a conglomerate. These strata appear only at a few points, forming ledges from four to five feet high, with a dip of 10 degrees southeast. They are surmounted by twenty-five feet of ash-colored loam, containing here and there small angular fragments of compact gray limestone.

I have been informed that about four miles south of this place extensive beds of soft gray limestone occur, that yield a good quality of quicklime, for which purpose they are extensively employed in the neighborhood. I was not, however, able to procure specimens of the rock for examination.

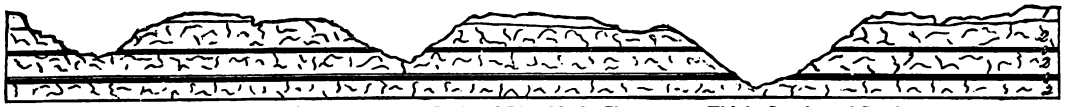
Distance, 16 miles.

April 6.—The prevailing formation encountered to-day was coarse reddish sand and sandy clay of the Quaternary Period, in places abounding with pebbles and small boulders of dark silicious rocks. Commingled with these also occur silicified fossil dicotyledonous wood, resembling in all respects specimens I obtained from deposits of the same geological age near the headwaters of the Brazos, Big Wichita and Red Rivers of Texas.

The fossil wood, as well as the pebbles and boulders, have doubtless been mainly derived from the destruction of Cretaceous strata.

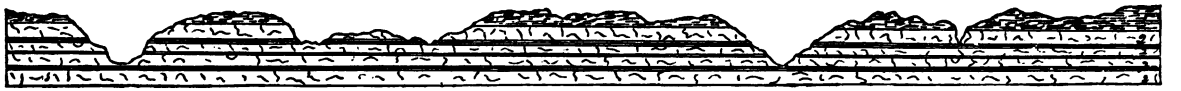
Section of Strata on Guadalupe River, Taken April 5, 1855.

Section of Strata, April 7, 1855.



1. Soft Limestone. 2. Red and Blue Marly Clay. 3. Thinly Laminated Sandstone.

Section of Strata near the Salt Lakes, April 8, 1855.



1. Pulverulent Limestone. 2. Indurated Blue and Yellow Marly Clay. 3. Laminated Sandstone.

The newer deposits entirely conceal those of older date until we reach Rice Creek, where we found a low exposure of soft ferruginous sandstone, similar to that observed on the Guadalupe River at Victoria. Soil poor, sandy, supporting a sparse growth of stunted oak.

Distance, $3\frac{8}{10}$ miles.

April 7.—For the first two hours our route led over gently undulating land, with a sterile, reddish, sandy soil, bearing sometimes a scattered growth of scrub oaks. This district, as well as that passed over yesterday, may be regarded as totally unfit for agricultual purposes, as the soil contains but few elements of nutrition, and the sub-soil is loose and poorly adapted for the retention of moisture.

At the distance of four miles we reached thick beds of red and blue marly clay, which continued to be largely developed during the remainder of the day's journey These strata I have no hesitation in referring to the Cretaceous Group. The clay is hard, tenacious, and contains thin and nearly horizontal seams of thinly laminated, fine grained, silicious sandstone, of light reddish and pink colors. This sandstone differs in character from any hitherto encountered. In many places the surface was found whitened with pulverulent carbonate of lime, exhibiting often a thickness of six or seven feet, and resting on the clay and sandstone, as shown in the accompanying section.

On striking this formation a marked change in the character of the country is at once observed. The soil becomes much more productive, and supports a luxuriant vegetation; in fact, we now find a desirable agricultural district, destined at no very distant period to become thickly inhabited.

Distance, $12\frac{1}{10}$ miles.

April 8.—Soon after leaving camp, we again struck heavy deposits of red sand and boulder formation, with its accompanying sterile soil, which continued for several miles, and was then succeeded by the Cretaceous marls, clays, and sandstones, overlaid by white pulverulent limestone, the whole being precisely similar in lithological character to that encountered yesterday. The limestone appears only near the surface, and is much thinner than that before noticed, nowhere exhibiting a thickness of more than a few inches, and appearing only at intervals. I was unable to detect any fossils either in it or the underlaying marls, which latter were often exhibited in ravines and bluffs to the height of fifty or sixty feet.

The country is gently rolling, and where the cretaceous deposits approach the surface the soil is often several feet thick. Timber mostly post oak and mezquite.

At Yorktown I saw a number of blocks of coarse grained red sandstone, said to have been procured from an extensive quarry situated about three

miles south of that point. The specimens of this rock examined were compact, and contain a large percentage of iron in the state of protoxide, which renders it unfit for building purposes. I was also informed that in the same neighborhood occur heavy beds of hard gray sub-crystalline limestone, well adapted for burning into lime. I could not obtain specimens of the rock, and was unable to determine its geological position.

After leaving Yorktown the land assumes an arenaceous character, the soil being in many places composed almost entirely of coarse red and black silicious sand, supporting here and there a sparse growth of stunted oak and mezquite trees. Occasionally, however, where the soft chalky limestone forms the surface rock, the soil is quite productive, and covered with rank vegetation.

Late in the day we reached a watering place known as the "Salt Lakes" Near this point, on the banks of a small stream, is exhibited a section of about thirty feet of alternations of indurated blue and yellow marly clay and coarse grained sandstone, surmounted with six feet of soft pulverulent limestone. The sandstone is soft, ferruginous, and disintegrates readily on exposure to the weather. The layers are from a few inches to a couple of feet in thickness. The character of the bluffs as seen here is shown in the accompanying section.

Distance traveled, 12½ miles.

April 9.—During the early part of our day's journey no material change was observed in the character of the geological formation, the strata maintaining nearly a horizontal position. The cretaceous beds were frequently well exposed, sometimes presenting sections of more than a hundred feet. I could not discover any traces of organic remains in any of these beds, although diligent search was made for them at various points. Soil usually of good quality, and bearing groves of mezquite. Sub-soil calcareo-argillaceous, sometimes arenaceous.

In a small ravine, about twelve miles distant from our last camp, we found an exposure of about twenty feet of quartzose ferruginous sandstone, in beds from three to four feet thick. This rock differs in a marked manner from any we have hitherto encountered, and resembles lithologically the sandstone of the Coal Measures that I have seen at Fort Belknap and other points in Texas.

It is coarse-grained, and often passes into a kind of millstone grit. Its color varies from deep red to ferruginous brown, and the beds dip at an angle of 10 degrees northeast.

This sandstone continues to be largely developed for several miles, and often exhibits local flexures and other evidences of disturbance. In a few places the rock is of a light bluish color, composed of fine grains, and would doubtless furnish a good building material.

Towards evening we came to an exposure of about twenty feet of yellow,

argillaceous, porous limestone of the Tertiary Period. This rock reposes partly upon the sandstone last described, and partly upon Cretaceous strata, and contains imperfect fossils of the genera *Tellina*, *Arca*, and *Infundibulum*. The layers dip about two degrees east southeast.

Soil, during the latter portion of the day's march, a productive vegetable loam.

Distance, 20½ miles.

April 10.—Three miles from the last camp we came to another exposure of yellow argillaceous limestone of the Tertiary Period, containing fossils of the same character of those of yesterday. These strata constitute the prevailing surface formation for several miles, and nowhere exhibit a thickness of more than fifteen or twenty feet.

The rock yields readily to the action of the weather, and consequently would not be well adapted for building purposes.

The white pulverulent limestone, marls, and sandstones of the Cretaceous System underlay the limestone just described, the whole resting unconformably upon coarse sandstone, which sometimes exhibits a thickness of forty feet, and is usually coarse-grained and more highly ferruginous than that observed yesterday.

About one o'clock we arrived at Cibolo Creek, a fine stream of clear water, which at this point flows between high bluff banks, and has an average width of about forty feet. Here the sandstone is well exposed, exhibiting a thickness of near sixty feet above the bed of the creek. In this vicinity several large fragments of excellent iron ore were picked up. In fact strong indications of this metal were frequently observed during the day.

Shortly after crossing the stream we encountered heavy beds of millstone grit and coarse conglomerate. These strata continued to be largely developed during the remainder of our day's march, presenting frequent indications of local disturbance, and a general inclination of about fifteen degrees northwest. The conglomerate is of various degrees of hardness, and consists of metamorphic rocks, cemented sometimes with a silicious and sometimes with a ferruginous paste.

The surface of the country passed over during the day was more or less broken and hilly, and often covered to the depth of several feet with dark, rich, vegetable soil. Sub-soil calcareo-argillaceous, occasionally arenaceous.

Distance, 17 miles.

April 11.—Our road during the day was over a broken, hilly country. For the first few miles no change was observed in the character of the formation. The conglomerate was constantly exposed, occasionally exhibiting a thickness of forty feet. The sandstone and gritstone were also largely developed. In one instance a well was sunk to the depth of sixty feet, wholly through these beds.

At the distance of about fourteen miles these rocks were succeeded by heavy beds of blue marly clay and hard and soft chalky limestone, which continued to be largely exhibited during the remainder of the distance to San Antonio.

Iron ore was again frequently met with to-day, and specimens of brown hematite of excellent quality were collected. The indications were such as to lead to the belief that this important metal exists here in considerable quantity.

The surface of the country for the first fourteen miles was thickly covered with loose pebbles and small boulders, derived principally from the destruction of the conglomerate. But as we approached San Antonio the soil became quite fertile and often clothed with luxuriant vegetation. Soil and sub-soil calcareo-argillaceous.

Distance, 20 miles.

SAN ANTONIO DE BEXAR.

While the expedition was detained several days in San Antonio, I employed my time in the examination of the geological structure of the country in that vicinity.

The Cretaceous System is here well developed, and consists for the most part of nearly horizontal strata of light gray limestone; thin bedded, fine-grained, and compact sandstone; and indurated marly clay. These beds correspond in geological position and, with the exception of the limestone, lithologically with the strata occurring between this place and Victoria, which we have already described.

The limestone, which constitutes the upper part of the Cretaceous System around San Antonio, has been extensively worn away by denudation. In some places it is very thin or entirely wanting; in others it forms gracefully rounded hills with gentle slopes; and at others again presents precipitously in bold and rugged escarpments. This last character is well exhibited near a small creek, known as the Salado, eight miles northeast of the city, where a range of gently sloping hills terminate abruptly to the southwest in a long line of bold and nearly vertical cliffs, over a hundred feet in height.

This rock varies considerably in character, and exhibits almost every degree of hardness. When first taken from the quarry it is often quite soft, white, or of a light gray color, and can hardly be distinguished from chalk; but after exposure to the atmosphere it soon hardens to form a most useful and durable building material, for which purpose it is largely employed in San Antonio. When first quarried it is easily cut with a knife, or common hand saw, into convenient sized blocks, which are exposed for a few days to the weather, and are then fit for use. While in the city I was shown a number of old buildings constructed of this material; one of them a church,

supposed tc be a hundred and fifty years old, has suffered comparatively little from decay, and is still used as a place of public worship. Near its upper portion the rock is often filled with dark nodules of flint, sometimes arranged in nearly parallel bands, varying from a few inches to a foot in thickness, but more frequently they are scattered promiscuously through the layers, and often so numerously as to form coarse conglomerate.

Many of the layers are highly fossiliferous; indeed, some of them are almost wholly composed of *Ostrea (Exogyra) læviuscula.* The fossils are usually in a good state of preservation and may be readily detached from the matrix. The most common species are *Ostrea læviuscula, Ostrea Pitcheri, Inoceramus Crispii, Cardium elegantulum,* and *Ammonites.*

A second variety of limestone, somewhat extensively quarried about one mile east of San Antonio, corresponds lithologically with the soft limestone so frequently encountered on our route from Victoria, and although somewhat largely employed in the neighborhood as a building material, possesses but little durability and will yield readily to the weather. It is so soft that it crumbles readily between the fingers, and resembles the softer varieties of chalk.

Still another kind, occurring however much less abundantly than either of the above, is a hard compact variety. It was only observed in detached fragments, strewn over the surface. I was unable to find the beds from which it was derived.

In one place a local deposit of soft porous limestone was observed, which, from its containing impressions of the stems and leaves of cedar trees and other existing plants, is evidently of very recent origin.

The following section will explain more fully the relative position, and as far as could be ascertained the thickness of the different strata composing the formation as observed in this vicinity:

No. 1. Flint nodules and rolled fragments of limestone. Thickness, 15 feet.
No. 2. Soft and hard white chalky limestone, containing flints and numerous fossils. Thickness, 200 feet.
No. 3. Soft chalky limestone. Thickness, 25 feet.
No. 4. Indurated blue and yellow marly clay, with thin bands of sandstone interstratified, and a thin seam of selenite. Thickness, 150 feet.

The bed (No. 4) of this section has been artificially excavated to the depth mentioned without reaching the base of the formation.

I have received from a gentleman residing in San Antonio specimens of *Exogyra costata* and *Inoceramus Crispii,* which were procured from the clay at the bottom of this well.

CHAPTER II.

FROM SAN ANTONIO DE BEXAR TO FORT CLARK.

April 16.—After leaving San Antonio, we traveled over a level and highly fertile prairie, thickly strewn in places with coarse angular fragments of white and grayish white limestone, often crowded with the same fossils as found in the vicinity of San Antonio. At the distance of four miles we encountered thick beds of indurated blue marly clay, which continued to be frequently exhibited until we arrived near Leon Creek, where it disappeared beneath the limestone, and was not again met with during the day. The suface now became undulating, more or less broken, and in places thickly covered with coarse silicious nodules, many of them encrusted with a white coating of carbonate of lime, which sometimes acted as a cementing material to form them into a coarse conglomerate. When broken they exhibited various shades of blue and brown, not unfrequently crossed by parallel lines. They have been derived from the disintegration of the adjacent limestone, in which they were often found embedded in great numbers.

At the crossing of Leon Creek a good section is exposed of nearly horizontal layers of white pulverulent limestone, with nodules of flint, and fine-grained greenish calcareo-silicious sandstone. The limestone is superimposed upon the sandstone, and is itself surmounted by about ten feet of partially consolidated detritus of coarse angular and rounded fragments of compact bluish-gray limestone, containing an abundance of water-worn fossils of the following species: *Exogyra costata*, *E. arietina*, and *Pecten quadricostata*. From the general appearance of the fossils they evidently could not have been transported far.

Near this locality occurs a low exposure of soft light-gray earthy limestone, containing fossils evidently of the Tertiary Era. This rock is only visible at a few points, resting directly on the Cretaceous Limestone. The larger part of the formation appears to have been removed by denudation.

The soil, during the day's march, was thick and very productive. Subsoil mostly calcareo-argillaceous.

Distance, 12 miles.

April 17.—A half mile from our last camp we reached a gently sloping prairie, thickly studded with small hillocks and ridges, varying from a few inches to several feet in height. These are of frequent occurrence throughout various portions of Texas and the adjacent Indian Territories, and are everywhere known by the name of "*Hog Wallows.*" Wherever they occur they impart to the face of the country a peculiar waved appearance, and are generally supposed to indicate a rich soil.

As we progressed the surface became more rolling, and often thickly coated with fragments of limestone of the same character as that met with yesterday. This deposit is sometimes accumulated to the depth of ten or twelve feet, and not unfrequently is loosely cemented with calcareous matter. Two miles to the east of our road and about six miles from the last camp, there occurs an extensive exposure of hard gray sub-crystalline limestone and thin bedded quartzose sandstone, the whole presenting a dip E. S. E. of about 2 degrees. These rocks are hard and durable, and afford excellent building materials, for which purpose they are already somewhat extensively employed in the neighborhood.

After traveling eight miles the country became still more hilly and broken, and at the same time the strata presented more or less evidence of local disturbance, but did not differ lithologically or paleontologically from the beds already noted. The pulverulent limestone still continues to be frequently seen, often exhibiting a thickness of fifteen or twenty feet. About ten o'clock we came to a small stream of clear water, along the margin of which is an exposure of about ten feet of yellow and reddish silicious limestone, containing rounded masses of flint, and compact gray limestone, replete with organic remains, chiefly, however, *Exogyra costata*. In places the rock is highly discolored with oxide of iron, and is undergoing rapid disintegration. The general dip is about 2 degrees to the west.

Shortly after leaving the creek we entered an extensive and nearly flat prairie, of but little geological interest. It extends to the Medina River, which is about seventy-five feet wide, and flows over a bed of solid limestone. The water is clear and strongly impregnated with carbonate of lime. Its temperature was found to be 77 degrees F. On either side of the stream are high bluffs, one of which exhibits a vertical section of thick-bedded yellow, brown, and white limestone, with alternating bands of soft blue shale, surmounted with loose detritus derived from the destruction of these beds. The whole cliff is replete with fossils, but owing to the softness of the rock they are very poorly preserved. The most abundant forms are, *Ostrea vesicularis*, *Pholadomya* (allied to *P. elegantula* D'Orb.) and *Trigonia* and *Pecten* of undetermined species. The accompanying section shows the strata at this locality.

The soil, during the greater portion of the day's march, was a deep and highly productive vegetable loam; sub-soil calcareo-argillaceous.

Distance, 16½ miles.

April 18.—Shortly after crossing Medina River we ascended by a gradual slope to the base of an extensive range of limestone bluffs from one to two hundred feet in height, which stretch irregularly across the country in a northwesterly and southeasterly direction as far as vision extends. They constitute the beginning of a series of abrupt ascents leading to the elevated table land of the *Llano Estacado*. As well as I was able to determine,

they are composed of nearly horizontal layers of white and light grayish limestone, with nodules of flint embedded. Reaching the summit of these, we found ourselves upon a broad and gently sloping plain, over which we traveled several hours. Its surface is often thickly strewn with rounded masses of flint and angular fragments of limestone, the latter sometimes passing into a hard light drab-colored variety, which, from its firm texture and uniformity of composition, is well adapted for lithographic purposes. It breaks with a smooth conchoidal fracture, and is susceptible of a good polish.

After traveling ten miles we arrived at a range of hills with gentle slopes and varying from two to three hundred feet in elevation. Their general bearing is northeast. The cretaceous strata are here strongly upheaved, as well as fractured, dipping on either side of the line of strike at angles varying from 40 to 50 degrees. The rock is of a light gray or yellow color, hard, and sub-crystalline, and abounds in fossils; but as the matrix is extremely hard, they are obtained with difficulty. I found here undescribed fossils of the genera *Arca*, *Cardium*, and *Buccinum*, also fragments of a crustacean of the genus Callianassa, very similar to *C. Danai*, recently described by Messrs. Hall and Meek.

Four miles beyond this place brought us to a small stream of clear water, where the cretaceous strata were again well exposed in nearly horizontal layers, containing fossils of the same character as those last mentioned.

Soil and sub-soil the same as seen yesterday.

Distance, 13½ miles.

April 19.—Our march to-day was over an elevated and highly fertile flat prairie, of but little geological interest. In the evening we encamped near the valley of the Rio Seco, which is here about a half mile wide, and bounded on the west by a range of high bluffs of nearly horizontal strata of white chalk, with flints embedded, resting on blue marly clay, the whole overlaid by about twenty feet of drift. The chalk presents a thickness of about twenty-five feet, and, although less pure, resembles in chemical composition and external character the foreign commercial article. This will doubtless prove of considerable economical importance. The embedded flints are from one to six inches in diameter, and are scattered promiscuously through the mass. They are more or less rounded, and in color vary from light brown to deep blue and black. Fossil remains were detected in several of them.

The underlying clay exhibits a thickness of over a hundred feet, and is the same lithologically as that seen at San Antonio. Its upper portion is banded with numerous thin seams of fine grained yellow and gray argillaceous limestone, often foliated, and containing minute scales of *mica*. These strata crumble readily on exposure to the weather. The dip is about 1 degree E. S. E.

Section of Strata on Medina River, April 17, 1855.

1. Detritus. 2. Cretaceous Limestone. 3. Blue Shale.

Section of Bluffs on Rio Seco, April 19, 1855.

1. Sub-soil. 2. Diluvium. 3. White Chalk with Flints. 4. Marly Blue Clay with thin seams of Limestone Interstratified.

Geological Section on Rio Frio, April 21, 1855.

No. 1. Quaternary or Bluff Formation. 2. Drift. 3. Cretaceous Limestone. 4. Basalt.

The accompanying section, taken about one mile from our evening camp, indicates more clearly the character and position of the strata composing these bluffs.

Distance traveled, 15 miles.

April 20.—Shortly after crossing the Rio Seco we ascended the bluffs above described. These were observed stretching somewhat irregularly north and south for many miles. They constitute the second of the series of terraces leading to the elevated plateau of the Llano Estacado.

The Rio Seco at the point of crossing is of moderate depth, and possesses a wide, clayey bed. The water is clear and calcareous. Temperature 79 degrees F.

We next traveled for several hours over a gently sloping and very fertile mezquite prairie, upon the surface of which the Cretaceous Limestone and detritus were often exhibited. The detritus is in places firmly cemented with calcareous paste, and appears more angular and coarser than that noticed yesterday. Its thickness is from ten to forty feet, and it contains occasionally fragments of soft yellow sandstone. We are evidently approaching the source of this deposit.

At the distance of eight miles we came to a small creek, whose banks exposed about ten feet of soft porous limestone, containing flints and an abundance of organic remains, chiefly of the following species: *Exogyra arietina*, *Nucula* (undt. sp.), *Baculites asper*, and *Cassidulus aequoreus*. The two last are especially interesting, as they likewise characterize the Ferruginous Sand Formation of the Cretaceous Group of Prairie Bluff, Alabama.

After crossing this stream the surface of the country becomes much more hilly and broken, and in many places contains small springs and rivulets of clear water. Indeed, in this respect we have as yet experienced no deficiency whatever; for with a few exceptions the entire country between this point and San Antonio is well watered by springs; and where these do not occur, excellent water may almost always be obtained by means of wells, which need seldom or ever be excavated to any great depth.

A travel of four miles farther brought us to the Rio Sabinal, a sluggish stream, with a wide, gravelly bed. Here the Cretaceous Limestone, the same as last mentioned, is again exposed in nearly vertical bluffs, in some places over fifty feet high.

Soil mostly dark and highly productive; sub-soil calcareo-argillaceous.

Distance, 12½ miles.

April 21.—Leaving the Rio Sabinal we traveled over a highly undulating and rocky prairie, underlaid by the same rocks as noted yesterday. About ten miles north of our road occurs a range of rugged conical hills, apparently from two to three hundred feet high. These rise abruptly from a basin-shaped depression in the prairie, and in general outline differ in a

marked manner from any hitherto encountered, from which I am led to the belief that the rocks composing them belong to the eruptive class.

At the distance of ten miles we reached a series of abrupt rocky steps, extending across the country in a direction nearly north and south, and varying in height from twenty to one hundred feet. All of them are composed of hard light-colored limestone of the Cretaceous Period. Ascending these we traveled for several hours over a gently rolling plain, covered in many places with dark rich soil. The formations here present evidence of disturbance, being inclined at high angles, but they have undergone little or no alteration in texture, and are crowded with fossils, chiefly *Inoceramus mytiloides* and *I. Crispii.*

As we progressed the surface of the country became much more uneven, and here and there divided by deep ravines, whose sides often exposed vertical sections of limestone many feet in thickness.

Late in the day we arrived at the Rio Frio, a beautiful, clear stream, about one hundred feet wide, with a rocky bed. Here projects abruptly from the water's edge a long line of vertical cliffs, from a hundred to a hundred and fifty feet in height, and exhibiting about midway the exposure an outburst of dark green basalt, with crystals of chrysolite disseminated through it. On either side of the eruptive mass the sedimentary strata are strongly upheaved, contorted, and metamorphosed, as exhibited in the accompanying section.

The basalt near its base possesses an imperfect columnar structure, and is intersected in various directions with veins of calcite. At the distance of half a mile on either side of the eruptive rocks, the Cretaceous strata, though much contorted and upheaved, have undergone but little metamorphic change. They contain *Inoceramus mytiloides*, *Inoceramus Crispii*, and an undescribed species of *Ammonite.*

Fragments of silicified fossil wood occur in great abundance in the bed of the Rio Frio. One of the specimens examined is about seven feet long by eighteen inches in diameter, and from its size and perfect preservation, the bark being nearly entire, it could not have been transported far. All the specimens examined have the structure of dicotyledonous wood, and resemble closely some examples I collected near the head of Red River.

The water of the Rio Frio contains a good deal of calcareous matter; temperature 70 degrees F.

Soil and sub-soil observed during the day the same as on yesterday.

Distance, 13½ miles.

April 22.—Crossing the stream we ascended by several benches to an elevated rolling prairie, with a dark rich carbonaceous soil, and exhibiting frequent outcrops of white and light-gray Cretaceous Limestone. The strata are frequently folded, fractured, and in some places highly metamorphosed.

After traveling eight miles we arrived at Fort Inge, where occurs another outburst of dark colored basalt, rising above the general surface to the height of two hundred and fifty-five feet, from a sub-quadrangular base about five hundred yards long and two hundred yards broad. On either side the sedimentary strata are upheaved and highly metamorphosed. This protrusion is of the same composition and in all other respects similar to that examined yesterday. At the distance of about ten miles in a northwesterly direction other hills are seen, which, from their dark color and close general resemblance to the one last described, are undoubtedly of similar composition.

From Fort Inge to the crossing of Nueces River, a distance of about eight miles, our road was over continuous beds of white chalky limestone and detritus, the former existing in nearly horizontal beds and containing characteristic Cretaceous fossils. At several localities near our road this formation was exposed in canyons and ravines to the height of more than a hundred feet. It is identical in appearance with that observed in the vicinity of San Antonio, and presents a slight general dip E. S. E.

The soil of this part of our day's journey was rich and supported a luxuriant growth of vegetation. Timber mostly mezquite and oak.

The river Nueces at the crossing is about one hundred yards wide, and flows over a flat bed of hard gray limestone. The water, as usual, contains a great deal of lime. In the bed of the stream I observed large fragments of silicified fossil wood, the largest of which was four feet long, twenty inches wide, and would weigh not less than five hundred pounds.

I was informed that near this point occurs a seam of bituminous coal, but was not able to visit the locality or obtain specimens of it.

Distance, 15½ miles.

April 23.—A short distance beyond the Nueces River we came to a succession of low abrupt benches, composed of limestone of the same character as before noted, and on ascending these found ourselves upon a broad and fertile prairie, whose surface was traversed by long parallel ridges, of variable height, extending in a northeasterly and southwesterly direction. These ridges were found to correspond with the flexures of the strata, which are here strongly disturbed. The limestone is about double the hardness of chalk, and contains flints and Cretaceous fossils. In many places the ground is thickly strewn with small angular fragments of red and black iron ore.

As we progressed the Cretaceous formation was found to exhibit frequent flexures, and finally assumed a decided metamorphosed character, being converted into sub-crystalline gray and deep purple limestone, very hard and compact in its texture. This area of disturbance extends about ten miles east and west, but no eruptive rocks were observed during the day.

At Turkey Creek unaltered Cretaceous strata are again well seen, dipping gently E. S. E. Fossils chiefly of the following species are there abundant: *Ostrea vesicularis*, *Inoceramus Crispii*, *Janira Texana*, *Turrilites* (new sp.) and *Ammonites* (new sp.).

April 24.—During the earlier portion of our day's travel horizontal beds of white and light grayish chalky limestone were of constant occurrence. Eight miles from the last encampment the strata again presented evidence of disturbance, and after traveling a short distance farther they were found reposing at an angle of about sixty degrees on a mass of dark basalt, very similar to that encountered upon the Rio Frio and at Fort Inge. This outburst is about a mile wide, and its bearing is northeast and southwest. At its western edge the Cretaceous Limestone is again observed, inclined at an angle of about sixty degrees in a direction opposite to that on the east, and thence it continues to be seen at frequent intervals, often in undulated beds, until we arrive at Fort Clark, where it is again nearly horizontal.

The surface of the country during the latter portion of the day's march was somewhat broken. Small angular fragments of iron ore, the same as noticed yesterday, were again observed frequently strewn over the ground.

Soil and sub-soil the same as before.

Distance, 16¼ miles.

CHAPTER III.

FROM FORT CLARK TO THE LOWER EMIGRANT CROSSING OF THE RIO PECOS.

April 26.—Shortly after leaving Fort Clark I observed several miles north of our road a number of conical hills, very rugged in their outlines, and bearing a close resemblance to the hills of basalt before encountered. They doubtless have the same geological structure.

During the day we continued to travel over white and grayish white limestone in thick beds, occasionally more or less folded. This rock agrees lithologically as well as paleontologically with the building stone of San Antonio, and is now employed in the construction of the government buildings at Fort Clark, for which purpose its softness and the ease with which it is wrought, together with its property of acquiring hardness on exposure, renders it exceedingly valuable. In ravines at several points I saw exposures of this rock from eighty to a hundred feet thick.

The surface of the country traversed to-day was gently rolling, and often thickly covered with fragments of limestone, among which loose masses of brown iron ore were frequently observed.

Soil dark, calcareous, and highly productive.

Distance, 9½ miles.

April 27.—No change in the character of the strata was observed during the first few miles of this day's travel. The general surface of the country is flat, although frequently traversed by ravines, in which the Cretaceous rocks are well exhibited. From some of these ravines specimens of *Ammonites vespertinus*, *Inoceramus Crispii*, and other cretaceous fossils, were obtained.

In about ten miles we again encountered heavy deposits of fragments of Cretaceous Limestone, often firmly cemented with calcareous matter, and agreeing in every respect with that encountered east of the Rio Frio. The country at the same time was quite uneven, and intersected in every direction by rocky canyons, from thirty to forty feet in depth, and which have been excavated by running water.

About eleven o'clock we reached the Arroyo Pedro, a clear stream of excellent water, with a broad, flat, rocky bed. Here is an exposure, upwards of a mile in length, of cream colored, compact, brittle, fine textured limestone, breaking with a conchoidal and splintery fracture. Many of the layers are susceptible of a good polish, and some present all the characters of an excellent lithographic limestone. The beds exhibit a thickness of about fifty feet, and their geological position is above the white chalky limestone. No fossils were detected in any part of the mass.

Fragments of iron ore were again observed strewn over the surface at a number of points to-day.

Soil and sub-soil the same as before.

Distance, 14¼ miles.

April 28.—For the first eight miles after leaving the Arroyo Pedro our road led over a gently rolling mezquite prairie, with fragments of limestone scattered over the surface, and possessing a dark, rich soil. Beyond this the country became more hilly and broken, and often cut up by deep canyons, with sides formed of precipitous walls of limestone. This limestone is of various degrees of hardness, sometimes very compact, and emitting a ringing sound when struck with the hammer, and at other times so soft that it may be crushed readily between the fingers. The width of the canyons varies from fifty to eighty feet.

About eight o'clock A. M. we attained an elevated part of the road, whence we had an excellent view of the broad and fertile valley of the Rio Grande, estimated to be about eight miles distant; and beyond this, say twenty or thirty miles, a range of mountains was dimly visible.

After traveling for several hours over a hilly and rather broken country, we reached a group of isolated, truncated, conical hills of limestone, three hundred feet high, and beyond these encountered a succession of abrupt terraces of Cretaceous Limestone, varying from one hundred to two hundred and fifty feet in height. These form the eastern border of an elevated table land that stretches irregularly for many miles in a northwesterly and southerly direction. We here struck the San Pedro, or "Devil's River," a broad stream of clear water, which winds its way through a deep and rugged canyon. This remarkable canyon is upwards of a hundred yards wide at the entrance, and presents on either side nearly vertical walls of white, gray, and yellow limestone, in nearly horizontal beds. The layers vary greatly in compactness, some of them being soft like chalk, and others extremely hard. This difference in the character of the beds causes them to weather unequally, giving to the sides of the canyon a remarkably picturesque appearance. As we advance the walls increase in altitude, and at one mile from the entrance they rise to nearly four hundred feet above the bed of the river. In some places large caverns, with arched ceilings, have been scooped out of the rock, while in others isolated sharp pointed columns are seen standing at various distances from the sides of the canyon.

On reaching, after some difficulty, the summit of the table land, we had an extensive view of the adjacent country, which exhibits evidences of denudation on a large scale. The surface is everywhere traversed by rocky canyons, some of them many yards in width; here rude, conical, flat-topped hills of limestone project abruptly to the height of two or three hundred feet; there extend long ranges of lofty cliffs, or gently sloping ridges, sometimes close together, at other times miles apart; while in the distance

long lines of bold and rugged escarpments mark the borders of a still more elevated country than that upon which we were standing.

The thickness of the Cretaceous Limestone at our evening camp, as determined by observations with the barometer, is about six hundred feet.

The strata here are replete with characteristic Cretaceous fossils. They are, however, confined chiefly to two rather broad bands, one situated near the bed of the river, and the other toward the summit of the cliffs. In the lower band we recognize the following forms: *Exogyra arietina; Janira Texana; Janira quadricostata; Cardium Sancti-Sabæ; Ostrea vesicularis; Terebratula Wacoensis; Turrilites Brazoensis;* and *Turbo, Holectypus, Toxaster,* and plants of undetermined species.

In the upper band the fossils are quite distinct from those of the lower band, and all of them appear to be of undescribed species. They belong to the following genera: *Conus, Nerinæa, Pleurotomaria, Turritella, Lima,* and *Cyprina.*

The soil, during the latter portion of the day's march, was generally barren, and the surface of the country rocky.

Distance, 19½ miles.

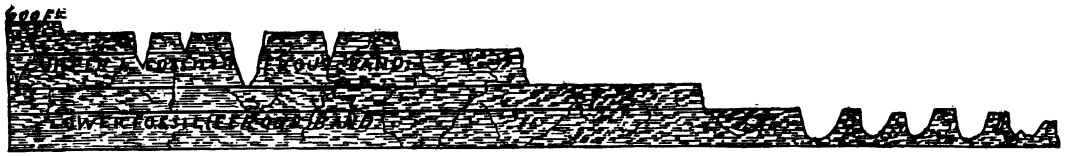
April 29.—Shortly after leaving camp we ascended from the canyon of Devil's River to an elevated rocky district, over which we continued to travel during the remainder of the day's march. The surface is here studded with ridges and abrupt conical hills, from two to four hundred feet high, and often situated several miles apart. The geological formation does not differ materially from that observed yesterday. The strata are often crowded with fossils, the same as above enumerated, confined to distinct bands, which form but a very inconsiderable portion of the mass, the intermediate beds being almost entirely destitute of organic remains. Our road was in many places thickly strewn with small angular fragments of dark oxide of iron, and at a single point I saw a thin seam of selenite.

The soil, for the first twelve miles, was barren, and composed mostly of disintegrated limestone. Afterward it was dark, calcareo-argillaceous, and moderately fertile.

Distance, 15⅛ miles.

April 30.—For the first few miles we passed over a barren and slightly undulating prairie, covered with coarse angular detritus, and studded with ridges and small conical hills, similar to those encountered yesterday. We then ascended by a gentle slope to a more elevated region, and shortly afterward entered a deep valley, bounded on either side by rugged hills of thin bedded limestone from four to five hundred feet high. The sides of this valley were at first widely separated, but they converged rapidly as we again approached the canyon of Devil's River, near which they were only a couple of hundred yards apart.

Section of Cretaceous Limestone, April 28, 1855.



Section of Hills of Cretaceous Limestone, May 5, 1855.

The canyon here was about five hundred feet deep and a hundred yards wide. The rocks composing its sides have in general the same lithological character as those near the entrance. There are, however, some differences worthy of mention. Some of the layers are nearly pure white, and resemble chalk, and others near the top contain nodules of flint, with fossils and hematite, the former sometimes so abundant as to constitute a very large proportion of the beds.

The thickness of the Cretaceous strata, as determined by barometrical observations and sections taken to-day, cannot fall far short of a thousand feet. The fossils collected are identical with those obtained in the lower band at the mouth of the canyon.

Devil's River, as seen to day, is an insignificant stream, having an average width of only about fifteen yards, and not exceeding two or three feet in depth.

The soil, during the day's march, was of the most unproductive character, consisting of little else than disintegrated limestone.

Distance, 20½ miles.

May 1.—During the entire day we continued to wind our way through the canyon of Devil's River, which was found to vary in width from a few hundred feet to three miles. Its floor is rough and uneven, but here and there covered with rich soil, bearing a luxuriant growth of grass. On either side of our road nothing was to be seen but abrupt conical hills and bare cliffs, which shoot upward to the height of five or six hundred feet, and mark, by their flat summits, the level of the table land above. They are everywhere composed of limestone of the same character as before noted, except near their summits, where occurs a hard grayish band, crowded with well preserved fossils, chiefly of the genus *Arca*.

The strata are frequently deeply excavated and fissured in such a manner as to require but a short stretch of the imagination to convert them into ruined temples and castles, or long lines of fortification. From the summit of the cliffs the eye encounters naught but a vast rolling surface, covered with loose fragments of limestone and coarse bunch grass, and intersected in various directions with deep and frightful rocky canyons, some of which appeared to be even more extensive than the canyon of Devil's River.

Distance, 14 miles.

May 2.—Our way continues through the canyon of Devil's River. No change in the character of the geological formation. Some of the beds contain fossils in the greatest profusion. The most characteristic forms are *Janira Texana; Lima Wacoensis; Gryphæa Pitcheri; Cardium multistriatum; Globichoncha elevata; Scalaria vertebroides;* and *Scalaria, Natica,* and *Pleurotomaria* of undetermined species. These fossils are chiefly confined to two bands, one near the base, and the other toward the summit of the cliffs.

The intervening beds, about five hundred feet in thickness, are very meagre in organic remains, and as far as my observations extend contain only a single species of corel (*Astrocœnia Guadalupæ* Roemer).

The part of the canyon through which we traveled to-day is from a half to three miles in width. It is often intersected by lateral canyons, some of them several hundred yards in length.

Soil and sub-soil the same as previously noted.

Distance, 7¾ miles.

May 5.—Near our last night's camp we saw a number of small shallow lakes of fresh water, derived from springs in the vicinity. The soil near these lakes is rich, and would produce well.

After winding for several hours amid rough hills and cliffs of Cretaceous Limestone, we finally reached the head of the canyon, and from thence ascended by an easy slope to the high table land, over which we traveled during the remainder of the day.

This table land, which corresponds in altitude to the summits of the cliffs, is somewhat undulating, and its surface overspread with a thick deposit of coarse angular fragments of light colored limestone. Here and there it is studded with isolated, truncated, conical hills, from one hundred and fifty to two hundred feet high, composed of nearly horizontal layers of Cretaceous Limestone. These hills are often isolated, and many miles apart, and serve as monuments to indicate the existence in former times of an elevated plateau, which has been almost entirely removed by denudation.

The strata of these hills contain many fossils of the same kind as those collected from the canyon of Devil's River.

Soil, for the first nine miles, calcareo-argillaceous, and moderately fertile, but afterward barren.

Distance, 16½ miles.

May 6.—Shortly after leaving camp our road descended into a broad uneven canyon, two hundred feet deep, bounded on either side by ranges of rugged cliffs, and sharp conical hills, the former often fissured, and apparently crumbling rapidly under the influence of the weather. In places the limestone is highly ferruginous, and contains small nodules of black oxide of iron, and flints. The layers vary in color from dull white to dark brown and black, and are of different degrees of hardness, sometimes being quite soft, earthy, and resembling chalk, and at other times hard, crystalline, and resonant under the hammer.

Fossils were again observed in great profusion to-day. Besides many of the species last enumerated, I found *Ammonites vespertinus*, *Panopœa Texana*, *Monopleura Texana*, and *Ostrea carinata*, of which the two first are quite characteristic of the Cretaceous beds of Fort Washita.

Soil moderately fertile; sub-soil calcareo-argillaceous.
Distance, 12 miles.

May 8.—For the first six miles to-day we continued our way through the canyon, the walls of which were often deeply fissured, and sometimes presented a remarkable castellated appearance. We then ascended by a gradual slope to the upland, which we again found covered with coarse angular fragments of limestone. The strata wherever observed still preserves a slight inclination E. S. E.; but in general character do not differ from what has already been described.

After traveling about three miles farther we entered another deep canyon, through which we journeyed the remainder of the day. Its depth is from three to four hundred feet, and on both sides are presented sharp conical hills, and abrupt walls with deep fissures, and cleft by small lateral canyons. The rocks are in many places highly fossiliferous, and afforded some interesting specimens.

Late in the day we reached "Howard's Springs," a small stream of clear water, formed by the union of a number of springs which gush from beneath the limestone. The water is highly calcareous, and its temperature 71 degrees F.

The soil, as observed during the day, is variable in character; in some places deep, calcareo-argillaceous, and moderately fertile, and in others barren, and composed almost entirely of disintegrated limestone.

Distance, 16 miles.

May 9.—Leaving Howard's Springs we continued to wind our way through the canyon, which varied from a few hundred yards to several miles in width, exhibiting an uneven floor, and in many places a moderately fertile soil.

About eight miles from the springs we again reached the summit of the table land, over which we traveled the remainder of the day.

As before, the surface of the table land or plateau is here covered with coarse fragments of limestone, and is traversed by immense rocky canyons, some of them many miles in length. This feature, together with the almost entire absence of soil, imparts to the face of the country a remarkably sterile and forbidding aspect.

Distance, 15¼ miles.

May 10.—After a travel of about seven miles we entered another canyon, similar in all respects to the last. The strata of this canyon presents a slight dip E. S. E., and assumes a variety of colors—white, gray, yellow, brown, red, and black. In some places they are highly ferruginous, and contain nodules of flint in great abundance; at several points thin seams of selenite were observed traversing the limestone.

The principal fossils seen to-day are *Arcopagia Texana, Gryphœa Pitcheri, Janira quadricostata, Cardium multistriatum, Ammonites acuto-carinatus,* and *Pterodonta (Eulima) subfusiformis.*

Late in the day we came to Live Oak Creek, a beautiful stream of clear water, flowing over a rough, rocky bed. The temperature of this stream was found to be 70 degrees F.

The soil, during the greater portion of the day's march, was barren, being composed principally of disintegrated limestone; but in the vicinity of Live Oak Creek it is moderately fertile, and supports a sparse growth of oak trees.

Distance, 11 miles.

May 11.—Beyond Live Oak Creek our route lay over a broken, rocky region, characterized on all sides by rough hills and cliffs of thin-bedded Cretaceous Limestone, some of which attain a height of more than five hundred feet.

As we progressed through the canyon it widened rapidly, and finally opened into the broad valley of the Rio Pecos, which here pursues a tortuous course between rough hills and picturesque cliffs from four to six hundred feet high.

The water of this stream is of a deep red color, and contains some muriate of sodium. Its average width is about seventy-five feet. Temperature 70 degrees F.

The valley possesses a red clayey soil, which appears to be moderately fertile.

Near the bed of the river I observed a layer, a few feet thick, of coarse breccia, made up of fragments of limestone, loosely cemented with a calcareo-ferruginous paste.

Distance, 7¼ miles.

CHAPTER IV.

FROM THE LOWER EMIGRANT CROSSING OF THE RIO PECOS TO THE MOUTH OF DELAWARE CREEK.

May 12.—The greater portion of this day was spent in exploring the hills and cliffs in the vicinity of our camp on the Rio Pecos. The thickness of the Cretaceous Limestone here was estimated at not less than a thousand feet. In its lithological character it varies considerably from that previously encountered, consisting for the most part of hard, compact rock, often crystalline, and usually of a light bluish color. The greater portion of the mass is almost entirely destitute of organic remains, but near the summit of the highest hills I discovered a band of soft earthy limestone, of a bright yellow color, highly charged with elegantly preserved fossils, which have been determined by my brother, Dr. B. F. Shumard, to belong chiefly to the following species: *Ammonites acuto-carinatus* (Shum.), *Ceratites* (*Ammonites*) *Pedernalis* (Roem. sp.), *Pterodonta subfusiformis* (Shum.), *Scalaria vertebroides?* (Mart. sp.), *Natica* (*Globiconcha*) *tumida* (Shum.), *Arcopagia Texana* (Roem.), *Panopœa Texana* (Shum.), *Janira quadricostata* (Sow. sp.), *Exogyra Texana* (Roem.), *Gryphœa Pitcheri* (Mort.), *Homomya alta* (Roem.), *Curdium multistriatum* (Shum.), *Holectypus planatus?* (Roem.), and *Toxaster Texanus* (Roem.). In addition to these we found a number of species not yet described.

After leaving the Pecos crossing we wound our way amid rough hills and cliffs of the same geological constitution as those just described. Everywhere we found a barren soil, composed almost entirely of pulverized limestone.

Distance, 5½ miles.

May 13.—During the entire day we traveled through the valley of the Rio Pecos. For the first six miles the rocks do not differ in general appearance from those observed yesterday. Beyond this the hills assume a more regular outline and the cliffs are less rugged in their aspect. The former are generally smooth, of a conical form with truncated apices. At first they are closely aggregated, but as we progress they become widely separated by smooth and gently undulating prairie. Their height is from five to eight hundred feet, and they present every indication of having once formed a portion of the elevated table land, now several miles distant, and from which they have been separated by denudation. The different strata composing them are found to agree in every particular with those composing the table land. Near the summits of the highest of them the strata are very prolific in well preserved organic remains. The following are the

prevailing forms: *Ammonites vespertinus*, *Ammonites Marcyana*, *Pterodonta subfusiformis*, *Terebratula Wacoensis*, *Janira Texana*, *Lima Wacoensis*, *Cardium Sancti-Sabæ*, *Trigonia* (undt.), *Gryphœa Pitcheri*, and *Hemiaster elegans*. With these I also found examples of *Gryphœa* which are not to be distinguished from those figured by Mr. Marcon under the names of *G. Marshii* and *G. Tucumcarii*.

Near the base of one of the hills I observed layers of soft, thin-bedded, quartzose sandstone, about twenty feet in thickness. This rock is fine grained, of a light yellow color, and is conformable with the limestone. Thin seams of white gypsum and selenite were observed to occur at several points.

The surface of the valley is for the most part thickly strewn with coarse angular fragments of limestone, which are not unfrequently firmly cemented into calcareous breccia. Near the base of some of the hills this breccia often presents a thickness of twenty or thirty feet, and is of such extreme hardness as to be broken only with great difficulty.

Soil and sub-soil highly calcareous and barren.

Distance, 13 miles.

May 14.—Continued our way through the valley of the Pecos, encountering the same character of hills and cliffs as seen yesterday. The hills are often separated by wide intervals, and vary much in altitude, the highest of them being from six to eight hundred feet above the level of the Pecos. The cliffs are often deeply excavated, and at a distance present the appearance of a succession of hills. From their summits the table land may be seen stretching away for many miles, its surface everywhere broken and divided by rude rocky canyons.

The Cretaceous Limestone as observed to-day was found to vary considerably in texture at different points. In some places it was soft, earthy, and of a light yellow color; in other places hard, compact, and more or less crystalline. Owing to their unequal hardness the different beds weather in such a manner as to leave horizontal bands projecting sometimes several feet, which in the distance give to the cliffs the semblance of lines of fortifications.

The yellow fossiliferous band, above mentioned, was again met with during the day, but organic remains are much more sparingly distributed. In a few places beds of coarse yellowish and reddish quartzose sandstone were interstratified with the inferior layers of limestone in beds from ten to thirty feet in thickness.

The Rio Pecos as observed during the day presented an average width of about seventy-five feet, and flows over a hard rocky bed, with low bluff banks of red loam on either side. The water is highly charged with red sediment and impregnated with common salt.

Soil moderately fertile.

Distance, 11¾ miles.

May 15.—In its general appearance and geological structure the region of country traversed to-day differs but little from that of yesterday. In places the strata were found to be more or less arenaceous, and everywhere appear to be undergoing rapid disintegration.

The width of the valley of the Rio Pecos is from five to ten miles, the surface dotted over with truncated conical hills, occasionally grouped together in small clusters, but generally separated by intervals of five or six miles. Usually they are much smaller than those encountered yesterday, and everywhere present a strikingly uniform character.

The surface of the country still continues to be often thickly covered with coarse angular fragments of fossiliferous Cretaceous Limestone, occasionally cemented with great firmness by calcareous matter.

Soil thin and moderately fertile. Sub-soil calcareo-argillaceous.

Distance, 9 miles.

May 16.—Still continue to travel through the valley of the Pecos, which is observed to increase gradually in width, but otherwise does not differ from the portion traveled through yesterday. Geological formation the same as before. The line of cliffs on either side of the valley exhibits an altitude of from six to eight hundred feet, and presents a less rugged outline than those seen yesterday. Fossils are abundant, but, as before, confined chiefly to two principal bands, one near the summit and the other near the base of the cliffs. With many of the species above enumerated, I collected examples of *Trigonia crenulata*, *Lima Wacoensis*, and *Janira Texana*.

The course of this part of the Rio Pecos is remarkably tortuous, and its average width about eighty feet. The banks are low and composed of red clay. Small lakes of clear water were met with at a number of points, which upon being tested proved to be strongly impregnated with salt, and the surface of the ground in their immediate vicinity is often whitened with saline efflorescences.

At our evening camp the valley of the Pecos presented a width of nearly twenty miles. Its surface is rough and broken, but sustains a good soil.

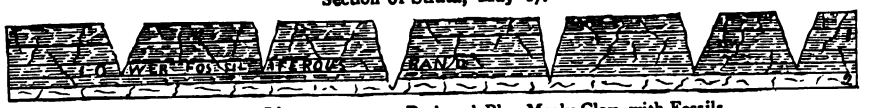
Distance, 16 miles.

May 17.—Continued our course through the valley of the Rio Pecos, which is still characterized on either side by abrupt cliffs, but they are now often widely separated, and do not anywhere exceed four or five hundred feet in height. In places they are deeply fissured, and sometimes large detached portions of the table land are to be seen standing out several miles from the parent mass.

The strata present a slight but uniform dip to the E. S. E., and everywhere appear to be rapidly yielding to the influence of the weather. In

800 ft. Section of Hills of Cretaceous Limestone. May 13, 1855. 810 ft.

Section of Strata, May 17.



1. Cretaceous Limestone. 2. Red and Blue Marly Clay, with Fossils.

Section of Strata, May 21.

1. Cretaceous Limestone. 2. Marly Clay with Seams of Sandstone interstratified. 3. Diluvium.

the lower fossiliferous band I collected the following fossils: *Ammonites vespertinus*, *Scalaria vertebroides?*, *Turritella* sp. ?, *Gryphæa Pitcheri*, *Ostrea crenulimargo*, *Janira Texana*, *Lima Wacoensis*, *Trigonia crenulata?*, *Terebratula Wacoensis*, and *Pygaster*, *Fusus*, *Opis*, and *Cardium* of undescribed species.

Toward the latter portion of the day we found nearly horizontal layers of red and blue indurated marly clay beneath the limestone. This clay agrees lithologically in all respects, save in color, with that observed in the vicinity of San Antonio, and is in several places crowded with an angulated variety of *Gryphæa Pitcheri*.

The valley as observed during the day varies from twenty to twenty-five miles in width, and the surface is in many places rough and broken.

Soil marly and fertile; sub-soil calcareo-argillaceous, in a few places arenaceous.

Distance, 15½ miles.

May 18.—After traveling a few miles from our camp of last evening, the valley through which we have been passing for so many days widens rapidly, and soon terminates in a broad, open, and gently undulating plain. Here the Cretaceous Limestone, while still preserving a nearly horizontal position, terminates abruptly to the west and northwest in bold, rugged precipices, from four to six hundred feet in height.* These are to be traced, stretching somewhat irregularly north and southwest, as far as vision extends, marking the edges of the table land and serving to indicate the great extent to which the strata of this region have been removed by denudation.

The surface now assumes a deep red color, and is everywhere marked by small hills and ridges of indurated red marly clay, which are for the most part gently rounded and from ten to forty feet high. The summits of the highest of them are thinly capped with nearly horizontal layers of Cretaceous Limestone, generally soft, of light grayish and yellowish colors, and with imperfect fossils of the same character as those of the cliffs.

The Rio Pecos as observed during the day has a width varying from sixty to eighty feet, and still continues to flow between low bluff banks of red clay. The water is highly charged with deep red sediment, and still contains a small percentage of saline matter. On either side of the stream there extends a chain of small, shallow, saline lakes, and the adjacent ground is often covered with an efflorescence of chloride of sodium, usually about a fourth of an inch in thickness.

Soil moderately fertile; sub-soil calcareo-argillaceous, occasionally arenaceous.

Distance, 16 miles.

*These cliffs are laid down on some of the maps as the "Castle Mountains." It is hardly necessary to state that no mountains occur in this portion of Texas, the so-called Castle Mountains being nothing more than the abrupt borders of the Table Land.

May 19.—Our way still leads over rolling and gently ascending prairie, its surface often whitened with saline efflorescences, and presenting here and there small patches of Cretaceous Limestone and detritus. The former is usually soft, white or of a light grayish color, and resembles very closely the pulverulent limestone observed in the vicinity of San Antonio. From the harder varieties a few imperfect characteristic cretaceous fossils were obtained. The prevailing formation consists for the most part of indurated red and blue marly clay, with intercalations of soft yellow and pinkish fine grained quartzose sandstone. The sandstone does not anywhere exceed two or three feet in thickness. It is usually thinly laminated, and traverses the clay in nearly horizontal bands. During the day sections of sixty or eighty feet of these strata were exposed, and near the base of one of them the sandstone was found to contain small rounded pebbles of eruptive rocks.

The Pecos still pursues a tortuous course, and lakes of highly saline water abound in its vicinity. The ground is also frequently coated with white saline efflorescences. Soil marly, in some places arenaceous; sub-soil calcareo-argillaceous and argillo-arenaceous.

Distance, 16½ miles.

May 20.—In general appearance and structure the country traversed to-day differs but slightly from that of yesterday. As we advance the soft pulverulent limestone is better developed, and presents often a thickness of ten or fifteen feet. Its stratigraphical position is immediately over the marly clay.

At the distance of twelve miles we arrived at the rapids of the Pecos. Here the water descends impetuously for a distance of about twenty feet over coarse quartzose sandstone and conglomerate. The total amount of fall is about ten feet. On either side are high bluff banks of red marly clay, coarse quartzose sandstone, and pulverulent limestone, in nearly horizontal strata. The sandstone is soft, friable, and of red and gray colors. Near the base it passes into a conglomerate of well rounded pebbles of quartz, red porphyry, granite, and other varieties of eruptive rocks.

Soil and sub-soil the same as before.

Distance, 21½ miles.

May 21.—General formation the same as before. After a travel of three miles, over a nearly flat and moderately fertile district, we arrived at a range of low hills, composed of red and blue clay, sandstone, and conglomerate, surmounted by about ten feet of hard grayish limestone, the latter containing a few imperfect fossils, of which the most common species is *Janira quadricostata*. Dip 2 degrees E. S. E. These hills constitute the remains of a once continuous plain, the borders of which, by denuding agencies, have been made to recede, gradually, many miles to the east,

where, as we have already seen, they are abruptly defined by lofty and nearly vertical precipices.

As we progressed the surface became much more uneven, and sometimes covered with coarse drift deposits, consisting of quartz, jasper, chalcedony, and granite, often loosely cemented with calcareo-ferruginous paste, and with an average thickness of about three feet.

The red clay formation was seen in several places exposed to the height of nearly a hundred feet. South of our road, and at a distance of perhaps sixty miles, are seen the bold rugged chain of the Limpea Mountains, whose lofty peaks and sharp outline denote, even at this distance, their igneous character.

During our day's travel the pulverulent limestone frequently presented itself on the surface, but nowhere exceeded five or six feet in thickness.

The accompanying section, taken from a deep depression in the prairie, shows the character of the strata observed during the day.

Soil and sub-soil calcareous and calcareo-argillaceous.

Distance, 12¾ miles.

May 22.—For the first few miles after leaving camp we traveled over nearly flat prairie, underlaid by indurated red and blue marly clay, elevated but a few feet above the bed of the Pecos River; surface of the country for the most part barren, and frequently whitened with saline efflorescences.

About two miles north of our road, on the opposite side of the river, extends a range of clay bluffs, of a deep red color, containing small shining particles of selenite, and between these and the river are a number of small lakes of salt water. As we advance the surface becomes more or less undulating, and occasionally thickly strewn with coarse transported materials, composed almost entirely of rounded masses of hard light gray and white crystalline limestone, differing lithologically from any hitherto met with.

These rocks contain fossils which may be unhesitatingly referred to the Paleozoic Period, and to the upper division of the Carboniferous System. Among other examples collected were *Productus splendens* (Norw. & Prat.), *P. semireticulatus* (Mart.), *Fusulina* (sp. ?), *Chonetes Smithi* (Norw. & Prat.), *Spirifer plano-convexa* (B. F. Shum.), *S. lineatus* (Martin), *Rhynchonella* several undescribed species, and numerous stems of *Encrinites*.

These materials are often firmly cemented with calcareous matter, and their thickness is upwards of twenty feet.

At the distance of six miles we came to a small elevation in the prairie, on the summit of which occurs a thin layer of hard grayish Cretaceous Limestone, from which I obtained a few imperfect specimens of *Ostrea*. This rock agrees lithologically, as well as paleontologically, with that of the cliffs to the east. It continued to appear at intervals during the remainder of our day's march, but was only observed near the summits of the highest hills, and nowhere exceeded two or three feet in thickness.

Soft pulverulent limestone and sandstone were also again frequently met with during the day. In some places the limestone exhibited a thickness of fifteen or twenty feet. Its position seems to be directly beneath the hard limestone.

In several localities sections of eighty or a hundred feet of red and blue marly clay were exposed, with bands of finely laminated quartzose sandstone interstratified, and occasionally the upper beds were parted by thin seams of white saccharoid gypsum.

Late in the day we arrived at a small stream of clear water, highly charged with muriate of sodium. In its immediate vicinity the land is boggy, and occasionally thickly coated with salt, and emits an odor of sulphuretted hydrogen.

Salt lakes were also observed at frequent intervals along the Pecos River.

The accompanying section exhibits the character and relative position of the strata as observed to-day.

Distance, 15¼ miles.

May 23.—Alternating beds of red and blue marly clay, with intercalations of soft silicious sandstone, continued to be largely exhibited during the entire day's march, sometimes presenting sections of more than a hundred feet. Occasionally horizontal bands of white gypsum and selenite occur towards the upper part of the sections. The former is of various degrees of hardness, and in places passes almost insensibly into soft pulverulent limestone, which latter appears to be altogether confined to the surface, and nowhere exceeds two or three feet in thickness.

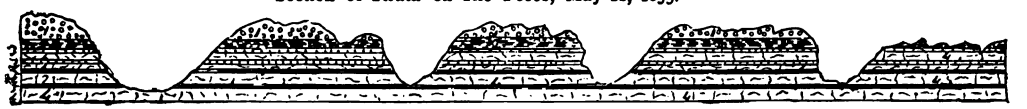
At ten miles we reached a range of low hills and ridges of hard Quaternary conglomerate, which prevailed the remainder of the distance to camp. This conglomerate is from thirty to forty feet thick, and consists, as on yesterday, of coarse rounded masses of hard crystalline limestone, firmly cemented with calcareous matter. Near the base of the deposit are several seams, from one to three feet thick, of coarse yellow sandstone, with metamorphic pebbles disseminated through it. Many of the limestone masses are almost entirely composed of organic remains belonging to the upper division of the Carboniferous System. The examples collected were mostly of the same species as those of yesterday.

Soil and sub-soil calcareo-argillaceous, in some places arenaceous.

Distance, 17 miles.

May 24.—Red and blue clay, with alternating bands of sandstone and gypsum, surmounted with conglomerate, were everywhere visible on our route to-day. The clay formation occasionally presents sections of more than two hundred feet. The conglomerate forms hills and ridges, with gentle ascents, from fifty to sixty feet high. The materials of which it is

Section of Strata on Rio Pecos, May 22, 1855.



1. Drift and Quaternary Conglomerate. 2. Hard and Soft Limestone. 3. Saccharoid Gypsum.
4. Marly Clay. 5. Quartzose Sandstone.

composed are somewhat coarser and more angular than those before noticed. The surface in many places still appears whitened with saline efflorescences, and on either side of the river small salt lakes are of frequent occurrence.

About eleven o'clock we reached a succession of hills and bluffs, from forty to sixty feet high, composed almost entirely of greenish gray and white gypsum and selenite. The greenish gray variety greatly predominates over the white and crystalline varieties, and differs somewhat in character from any previously encountered. It is hard, fissile, possesses a shining silken lustre, and contains a large admixture of sand. Between the different layers occurs a yellow calcareous earth, doubtless derived from the disintegration of the white pulverulent limestone, seams of which occur with the gypsum. The entire thickness of the gypsum deposit in this vicinity I estimate at about sixty feet.

Soil and sub-soil calcareo-argillaceous, in some places arenaceous, and in others it contains a large quantity of gypsum.

Distance, 14 miles.

May 25.—After leaving the gypsum bluffs we traveled over smooth and gently undulating prairie, often whitened with gypsum and soft powdery limestone. At the distance of six miles from the last encampment we again came to heavy beds of conglomerate, composed, as before, chiefly of limestone, and with an average thickness of about forty feet. In general it is much coarser than any previously observed, and contains blocks from eight to ten inches in diameter. Fossils of the same character as before noted were again detected in it in great numbers. This rock prevailed largely during the remainder of our day's march, everywhere imparting a rough and broken aspect to the country.

Along the Rio Pecos vertical sections of clay and sandstone were frequently exposed. The former has now assumed a uniform red color, and contains a great deal of gypsum, while the sandstone becoming much thicker and coarser. The dip is uniformly about 2 degrees E. S. E. These rocks constitute the bed of the river, which, owing to their unequal hardness, is often disturbed by rapids, while the clay mingling with the water imparts to it its characteristic deep red color and a slightly gypseous but not very disagreeable taste.

About twelve o'clock we arrived at a range of high bluffs of red clay and gypsum, overlaid by about forty or forty-five feet of conglomerate, and at the foot of them meanders a small creek of clear strongly saline water. The soil here is also covered with salt, and emits an odor of sulphuretted hydrogen gas.

Soil and sub-soil for the first eight miles calcareo-argillaceous; afterward arenaceous.

Distance, 11¼ miles.

May 26.—During the greater portion of this day's march our road was over a succession of gently rounded hills and ridges, from fifty to one hundred feet high, composed almost entirely of conglomerate. The thickness of this deposit increases rapidly as we advance, and the materials composing it are continually growing coarser. Some of the masses are over a foot in diameter, and, as before, consist almost entirely of fragments of hard white and gray crystalline limestone. Fossils of the same character as before were collected from it.

The red clay, soft earthy limestone, gypsum, and sandstone were also largely developed along our route to-day—but they were best exposed along the river, presenting there vertical sections often fifty or sixty feet thick. The sandstone is usually soft, deep red or purple, and often marked with small circular spots of light green and yellow.

A few miles before we reached our permanent camp near the mouth of Delaware Creek, we again struck hard Cretaceous Limestone, which increased rapidly in thickness and continued to show itself at short intervals during the remainder of our day's journey.

Soil and sub-soil sandy, calcareous, and calcareo-argillaceous.

Distance, 12½ miles.

CHAPTER V.

FROM THE MOUTH OF DELAWARE CREEK TO THE FOOT OF THE GUADALUPE PASS.

As the Expedition remained for several months encamped near the mouth of Delaware Creek, a favorable opportunity was afforded for examining minutely the geological structure of that vicinity and the Llano Estacado. The latter is to be seen from our camp, stretching for an indefinite distance eastward, in the form of an elevated and gently undulating plateau, thinly covered with short grass, and presenting generally but little variety of surface. It is abruptly terminated on the west by the Pecos River, which flows in a tortuous course, with an average width of about eighty feet, amid low hills and bluffs of conglomerate and limestone. Beyond the Pecos the country assumes a more broken and hilly appearance, and at the distance of sixty miles rise the lofty summits of the Guadalupe Mountains, of which the highest points had been observed long before we arrived at the mouth of Delaware Creek.

All the rocks of this vicinity, save the limestone noticed on our last day's journey, were found to differ somewhat in general character from those already described. The limestone here attains a thickness of over a hundred feet, exhibiting itself chiefly in the form of flattened conical hills and rough cliffs, sometimes with vertical faces, and in places rising above the creek or river bed to the height of fifty or sixty feet. The rock is usually hard, of a light cream color, earthy texture, and contains numerous spheroidal cavities, from a fourth to a half an inch in diameter, which are sometimes partially filled with loose ferruginous earth. In one locality the exposed edges of the strata were covered with an incrustation of salt a fourth of an inch thick. This limestone forms the bed of the Pecos River, and here gives rise to a succession of rapids. Fourteen miles to the east the same limestone becomes much softer, lighter colored, and resembles impure chalk, but does not there exceed in thickness thirteen or fourteen feet. Fossils are exceedingly rare in it. In a few instances I obtained imperfect specimens of *Exogyra* [?] *Pitcheri* and *Janira quadricostata*. Underneath the limestone we have the gypsum, clay, and sandstone, which are often well exposed in this vicinity. The gypsum is frequently found in connexion with white soft carbonate of lime, and presents an average thickness of about twenty-five feet. From the Artesian Wells, situated one fourteen and the other eight miles east of the Rio Pecos, vertical sections of the clay and sandstone were obtained to the depth of eight hundred and fifty-eight feet.

The clay is usually highly indurated, and contains more or less of an admixture of lime. In color it varies from nearly white to blue, brown, and vermilion. The intercalated layers of sandstone are generally softer than

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1. Alluvium. 2.

those previously encountered, and constitute by far the greater portion of the exposed thickness of the formation. The superior beds are often little else than loosely coherent sand; but at the base of the sections the strata are much firmer, of a light yellow color, and contain small rounded pebbles of eruptive rocks.

Besides the strata above described, the superincumbent Quaternary conglomerate is also largely developed. Near the junction of the Pecos and Delaware Creek this formation attains a thickness of near seventy feet, and appears mostly in the form of gently rounded hills and ridges, some of which terminate abruptly towards the river. With the exception of being somewhat coarser, and occasionally traversed by irregular bands of coarse yellow silicious sandstone, the materials composing it do not differ from those of the same formation last described. Many of the included masses are rich in organic remains, and present a considerable variety of species characteristic of the Carboniferous System, as follows: *Productus semireticulatus*, *P. splendens ?*, *Chonetes Smithi*, *Camarophoria Schlotheimi ?*, and *Fusulina*.

Commingled with these I found a few imperfect Cretaceous species in angular fragments of soft yellow limestone, as follows: *Arcopagia Texana*, *Janira quadricostata*, *Cardium multistriatum*, and *Gryphæa Pitcheri*. From the general appearance of these fossils they evidently could not have been transported far.

Directly south of Delaware Creek the strata are strongly folded and inclined in different directions at angles varying from twenty to fifty degrees. The period of disturbance appears to have been anterior to the deposition of the conglomerate, since the latter is found reposing unconformably in nearly horizontal beds on the ruptured edges of the older strata.

Section — is from a nearly vertical exposure extending along the west bank of the Rio Pecos from near the mouth of Delaware Creek S. S. E. for the distance of about a half a mile. Here the limestone is found dipping in opposite directions at angles varying from 20 to 30 degrees, the upper beds having been ruptured and widely separated, and the entire mass traversed from top to bottom by fissures ten or twenty feet wide, filled, chiefly, with small angular fragments of limestone, firmly cemented with calcareous matter. In one place, near the base of the section, the gypsum is exposed to the thickness of fifteen feet. It is for the most part white, amorphous, and resembles more or less loaf sugar.

Section No. — was taken from near the east bank of the Rio Pecos, several miles below the last. It exhibits a still greater amount of disturbance, the underlaying clay and sandstone being here well exposed, dipping in different directions at angles of from forty-five degrees to fifty degrees, and at the same time the ruptured edges of the limestone appear somewhat altered in texture, being harder, and sometimes fractured into small angular

fragments, firmly recemented, so as to give the rock a fragmentary or brecciated appearance. The sandstone is also harder, of dark red and purple colors, and thickly besprinkled with small green and yellow spots.

The extent of this region of disturbance could not be accurately determined on account of the leveling effects of the subsequent denudation and the thickness of the superincumbent deposits of more recent date; but from the fact that the limestone is observed twelve or fifteen miles both east and west of the Pecos River, in nearly horizontal strata, and appears merely in gentle undulations at our second camp a few miles south of the point where the last mentioned section was seen, it is highly probable that it does not in any direction exceed fifteen or twenty miles.

On the morning of the 23d of September we started from our camp near the mouth of Delaware Creek, still pursuing a westward course.

For the first few miles our road wound amid gently rounded hills and ridges of Quaternary conglomerate or limestone breccia, from thirty to a hundred feet high, with occasional exposures of Cretaceous Limestone ten or fifteen feet in thickness. Soil and subsoil calcareo-silicious. As we proceed the conglomerate gradually thins out, and finally appears only at intervals, while the limestone is much more largely developed, and forms short ridges and truncated conical hills, sometimes five or six hundred feet in height. Occasionally these were isolated and widely separated from each other, and sometimes grouped together in clusters of eight or ten. In general outline and composition they very closely resemble the hills and ridges previously encountered farther east, thus indicating pretty clearly that they constitute the remains of a once continuous table land, of whose former existence and subsequent removal by denudation they are the monuments. The dip of the strata is pretty uniformly about one degree E. S. E. Near the summits of some of the highest elevations, hard projecting bands of brown and light gray limestone occur, but, unlike those forming the summits of the hills and cliffs farther east, they are exceedingly barren of fossils, and have yielded after a careful search but a single imperfect specimen of *Mytilus*. In conformable beds beneath the limestone we find the red marly clay, sandstone, and gypsum, exhibited in nearly vertical sections, sixty or seventy feet in height. The gypsum is in places deeply discolored with oxide of iron.

The surface of the country during the greater portion of the day's march was found covered with powdered gypsum and white carbonate of lime, sometimes ten feet in thickness. Along the valley of Delaware Creek the soil is moderately fertile, and composed of sand, clay, and lime in variable proportions. The water of this stream is clear, and possesses a strong taste of gypsum. Temperature, 71 degrees F.

Distance, 9 miles.

Sept. 24.—For the first few hours our road was over thick beds of marly clay, gypsum, and limestone The clay varies in color from bright vermilion to deep blue. The gypsum in places presents a thickness of about sixty feet, and assumes every degree of compactness from the soft pulverulent variety noticed yesterday to compact bluish-white alabaster. The softer varieties often pass upwards, insensibly, into soft white carbonate of lime, sometimes fifteen or twenty feet thick. This is undoubtedly due to the disintegration of the gray limestone, which, wherever seen, is found gradually yielding to the influence of the weather.

As we continue to advance the compact limestone rapidly diminishes in thickness, and in a distance of six miles disappears entirely, and is replaced by thick beds of Quaternary conglomerate, or rather breccia, much coarser than any previously encountered and abounding in a great variety of fossils. We are evidently approaching the source of this deposit, since the fragments are not only larger and more angular, but the formation is increasing rapidly in thickness. In some places its thickness was estimated at from four to five hundred feet.

Soil, in some places moderately fertile, in others barren, and composed principally of soft carbonate of lime and gypsum.

Distance, 15¾ miles.

Sept. 25.—For the first few miles red and blue clay, gypsum, and pulverulent carbonate of lime were largely exhibited along our route; they then suddenly disappeared and were not again met with during the remainder of the day's journey.

At the point where they abruptly terminate strata of the Carboniferous System show themselves in low hills and ridges. They consist of yellow quartzose sandstone, surmounted by black, gray, and white limestone, as exhibited in the following section:

1. Heavy bedded compact white and light gray limestone.
2. Black thinly laminated limestone. 100 feet.
3. Dark gray thin bedded crystalline limestone. 50 feet.
4. Yellow quartzose sandstone, with thin seams of black compact limestone interstratified at its upper portion.

These rocks are unconformable with the Cretaceous strata, though the dip is still E. S. E.

Owing to the great thickness of the Quaternary deposits the upper white limestone is not well exposed just at this point, but at other places not far distant it presents a thickness of several hundred feet. It is usually a hard crystalline limestone, abounding in fossils identical with those so frequently observed in the conglomerate.

The organic remains of this limestone so far as they have been described

are as follows: *Productus semireticulatus* (Martin), *Productus splendens* (Norwood and Pratten), *Chonetes Smithi* (Norwood & Prat.), and *Spirifer planoconvexa* (B. F. Shumard). These species are regarded by geologists of the Western and Southwestern States as being characteristic of the upper division of the Carboniferous System, or Coal Measures.

From the dark gray limestone (No. 3 of the section) the following undescribed fossils were obtained, which, as far as my observations extend, are peculiar to this portion of the formation: *Rhynchonella*, *Straparollus* (two species), and *Phillipsia*.

No fossils were observed in the underlying sandstone. This rock is fine grained, more or less micaceous, and of moderate hardness. Although sometimes exposed in heavy massive strata, it is for the most part thin bedded and occasionally finely laminated. It contains near its upper portion bands of dark compact limestone from a few inches to two feet thick.

Denudation.—As we proceeded on our way the country everywhere exhibited the strongest evidence of denudation, being deeply excavated, and often appearing in detached hills, usually of a conical form, and sometimes separated from each other by intervals of several hundred yards. The limestone is now only occasionally observed capping the summits of the highest elevations, and nowhere presents a thickness of more than one or two hundred feet. Immediately south of our route the country is much cut up by deep valleys and rocky ravines; to the north the surface, although less broken, is nevertheless rough and thickly strewn with coarse angular fragments of limestone.

By following the windings of the different valleys our road was for the most part a smooth and gentle ascent, the rate corresponding pretty nearly with the dip of the strata, thus affording a firm foundation and other conditions highly favorable for the construction of a railroad. The Quaternary breccia still prevails along our route, with an average thickness of over two hundred feet, and contains angular blocks of limestone sometimes several feet in diameter.

Head of Delaware Creek.—About ten o'clock we arrived at the sources of Delaware Creek. This stream rises in a broad and fertile valley, and is formed by the united waters of several springs that issue from the base of the conglomerate and the upper portion of the sandstone, which constitutes the floor of the valley. These springs are contiguous to each other, but vary remarkably in character. When they issue from the conglomerate the water is clear, slightly calcareous, and possesses an agreeable taste; but when they flow from the sandstone they are highly impregnated with various saline ingredients, have a disagreeable taste, and emit a strong odor of sulphuretted hydrogen.

The Valley of Delaware Creek at this point is about two hundred and fifty feet deep, and its width is from a few hundred yards to several miles. It appears to have been hollowed out of the solid strata by denudation. On

either side are abrupt escarpments and hills of massive and thin bedded sandstone, surmounted by heavy and finely laminated strata of limestone, as exhibited in the following section, taken a few hundred yards from our evening's camp:

1. Heavy bedded gray and white limestone. 50 feet.
2. Finely laminated black limestone. 110 feet.
3. Heavy and thin bedded yellow quartzose sandstone, with thin seams of dark compact limestone interstratified. 100 feet.

The floor of the valley is generally smooth, but here and there marked with ridges and abrupt conical hills of sandstone and limestone from one to two hundred feet high.

Soil calcareous and calcareo-argillaceous, in some places silicious.

Distance, 8 miles.

Sept. 26.—During the day we gradually approached by a gentle ascent the eastern base of the Guadalupe Mountains. Our road, although marked on both sides with hills and deep valleys, is still smooth, and from the gentle and uniform dip of the strata capable of affording everywhere a firm and easy grade for a railroad.

The hills are for the most part gracefully rounded and from one to four hundred feet high. The valleys to the south are apparently much deeper than those met with yesterday. The strata seen to-day do not differ in character from those last described. In places the sandstone is exposed by denudation to the height of six hundred feet. The overlying limestones are confined mostly to the hills, and at some points exhibit a thickness of nearly four hundred feet. They are filled with fossils of the same character as those last enumerated.

The strata still present an E. S. E. dip, but with a gradually increasing angle. No evidence appears of sudden or violent disturbance, but the uplifting of the stratra has evidently been the result of causes operating in a uniform and very gradual manner. The subsequent denudation to which they have been so largely subjected imparts to this region a rough and broken aspect. It is only by following the different valleys, most of which appear to have a general east and west bearing, that a practicable and easy grade for a railroad may be obtained.

Independence Springs.—Towards evening we arrived at Independence Springs. From these a small stream of water flows for some hundreds of yards through a fertile valley, and then is lost amid deep rocky ravines. The springs, of which there are several, bubble up through nearly circular openings in the sand-rock that composes the floor of the valley. Each of these openings is surmounted by a deep and nearly circular basin, from five to ten feet in diameter, and capable of containing from two to four hundred

gallons of water. By enlarging these a constant supply of excellent water can always be obtained here in quantities sufficient to answer the purposes of a railroad. At one of these openings a pole was sunk to the depth of fifteen feet without reaching the bottom.

Near this place there are thin seams of dark argillaceous shale interstratified with the sandstone.

Soil during the day calcareo-argillaceous and moderately fertile.

Distance, 18 miles.

Sept. 27.—From Independence Springs to the eastern base of the Guadalupe Mountains, a distance of about six miles, our road led over a gradual ascent of several hundred feet. For the whole of this distance the dark thin bedded limestone and subjacent sandstone is well exposed. As we approach the mountains the inclination of the strata increases, the dip being about twenty degrees and the direction still E. S. E. At the mountains they are seen to pass under the massive white limestone, which, as we shall soon see, is here much better developed than farther east.

To the south, and apparently continuous with the line of upheaval of the mountains, the ruptured edges of the same strata are to be seen, presenting to the west rugged and nearly vertical escarpments from fifteen hundred to two thousand feet high, and extending southward as far as vision reaches. These cliffs are occasionally capped with light colored limestone, but generally this rock has been removed by denudation.

The Guadalupe Mountains, near the southern extremity, rise abruptly from a gently ascending surface, and attain at the highest point an altitude of nearly three thousand feet above their base and about eight thousand feet above the level of the ocean. The main axis or line of upheaval trends somewhat irregularly northeast and southwest. From our point of observation there is a gradual descent to the northeast, while to the south the range terminates abruptly in a frightful precipice upwards of two thousand feet high. Around the base of this precipice our road led by a gradual descent through a deep canyon composed on both sides of rough and nearly vertical cliffs. The eastern slope of the mountains is rapid towards the Plains, and marked by deep and rugged canyons often with nearly vertical sides. One of these canyons, situated near the southern extremity and known as "The Pinery," was explored for the distance of about a mile. At some points it is upwards of a half a mile wide, and bounded on either side by vertical or abrupt sloping walls of such extreme height that their summits appear often enveloped in clouds.

It is only, however, when observed from the west that these mountains can be contemplated in all their grandeur. Here extends an unbroken line of vertical precipices from two to three thousand feet in height, the faces of which are of such extreme smoothness as to be accessible only a few hundred feet above the base. The abrupt faces of these cliffs pursue a

general course parallel with the axis of upheaval of the mountains, which present the appearance of having been cleft vertically through their centers and the western halves removed. They attain their greatest elevation about one mile north of the southern extremity, from which point there is a gradual descent to the north and south.

Geological Structure.—The Guadalupe Mountains consist of white, gray, and bluish-black limestone and fine and coarse-grained quartzose sand stone, the whole appertaining to the upper division of the Carboniferous System, or Coal Measures. The white and gray limestone reposes in heavy beds upon the standstone, and exhibits the enormous thickness of more than a thousand feet. It is harder than any previously encountered, but in all other respects it is precisely of the same character as that seen at the head of Delaware Creek and between that point and the Guadalupe Mountains. It is remarkably rich in organic remains, a large portion of which are new to science, but others appear to be forms characteristic of the Coal Measures. Some of the layers of white limestone are composed almost wholly of remains of *Crinoidea*. I collected a number of species of fossils from the beds, as follows: *Productus semireticulatus*, *Productus splendens?*, *Productus Boliviensis?*, *Productus* undetermined, *Chonetes Smithi* (Norw. & Prat.), *Rhynchonella* several undetermined species, *Spirifer plano-convexa*, and *Avicula*, *Ostrea*, *Cypricardia*, *Straparollus*, *Cyathophyllum*, *Fenestella*, *Chætetes*, and *Phillipsia* of each one or more undescribed species.

With these occurs a slender *Fusulina* upwards of an inch in length, which appears to be quite distinct from the *Fusulina cylindrica* so characteristic of the Coal Measures of the Missouri River. There is also a brachiopod which possesses all the external characters of *Camarophoria Schlotheimi* (Verneuil sp.) of the Permian System of Russia.

From the dark limestone interposed between the white limestone and sandstone beds, fossils were collected identical with those occurring in the beds near the head of Delaware Creek.

The Sandstone is best displayed in the canyon and on the western side of the mountains. In the latter position it exhibits a thickness (estimated approximately) of from twelve to fifteen hundred feet. Towards the top it is soft, and contains fossils of the Coal Measures, frequently in great abundance, as follows: *Spirifer Meusebachanus*, *Athyris subtilita*, *Productus Boliviensis?*, *Productus* new species, *Spirifer plano-convexa*, *Bellerophon Urii?*, and *Fusulina*. At one point strata upwards of a hundred feet in thickness are composed almost entirely of the last mentioned fossil. The inferior layers are generally compact, coarse grained, and micaceous. At the base are intercalated bands of hard dark argillaceous shale, and beneath these are thin layers of dark compact limestone, which, at a locality a little north of the pass, is exposed to the thickness of five hundred feet. Diligent search was made for fossils in these beds, but no traces of any were detected.

The Pass.—As we wound around the southern extremity of the moun-

tains our road led first by a gradual descent over the upturned edges of the limestone strata, and afterwards the fine and coarse grained sandstone, shale, and underlying dark colored limestone were successively passed over. At the point where the line of survey diverges from the emigrant road the lower sandstone is largely developed, and from the E. S. E. dip and durable character it is capable of affording not only a firm and easy foundation for a railroad, but also the very best of materials for construction.

Beyond the foot of the canyon a range of hills from five to eight hundred feet high presents a precipitous face towards the east, extending irregularly for several miles in a direction nearly parallel with the mountains. In this range the dip of the strata is 25 degrees W. N. W., or in a direction contrary to that observed in the Guadalupe Mountains. But the rocks are in all respects similar to those of the mountains, a portion of the western slope of which they at one time formed, although at present separated by a deep valley several miles wide. Facing also in an easterly direction and about fifteen miles to the southwest there occurs an extensive range of rugged cliffs, from the summits of which the surface slopes gently towards the west. These cliffs, as well as could be determined at a distance, are from a thousand to fifteen hundred feet in height. Their bearing is nearly parallel with the escarpments south of the mountains, which they very closely resemble in general appearance, and doubtless have the same geological composition. Between the ranges is a broad and gently undulating valley, with its surface often dotted with small saline lakes.

Soil.—From Independence Springs to the summit of the Guadalupe Pass the surface of the country is rocky, but thickly covered in many places with dark carbonaceous and highly productive soil. Beyond this it is altogether unfit for cultivation.

Distance, 14 miles.

CHAPTER VI.

FROM THE FOOT OF THE GUADALUPE PASS TO DONNA ANA, NEW MEXICO.

Sept. 29.—After traveling for several hours through the deep valley above described, and over the same fossiliferous rocks observed yesterday, we emerged into a broad and gently undulating country, over which we continued to journey during the remainder of the day. The surface consists chiefly of tenacious red calcareo-argillaceous clay, coarse yellow quartz sand, and limestone detritus, which is often firmly consolidated by means of calcareous matter, and characterized by fossils different from those found in the mountains. Its general thickness is about ten feet.

Salt Lakes.—About three or four miles south of our road are several shallow saline lakes, the largest of them being from two to three miles in circumference. Owing to their pure whiteness they afford a remarkably pleasing contrast to the otherwise monotonous character of the surface. I have been informed that from these lakes salt may be readily obtained in almost any quantity, their flat beds after the evaporation of the water being often incrusted with it to the thickness of several inches.

At the distance of fourteen miles we came to a range of hills of fine yellowish silicious sand. These extend five or six miles southward, with an average width of about a mile. They are from twenty-five to forty feet high, and appear to be gradually shifting their position to the north. To the south they slope gradually towards the plain, but present abruptly in the opposite direction, where several of them at a recent period have partially covered a number of mezquite bushes so as to leave merely their tops projecting above the sand.

Soil and sub-soil for the first eighteen miles calcareo-argillaceous and silicious; afterwards highly calcareous and composed almost entirely of disintegrated limestone.

Distance, 24 miles.

Sept. 30.— *Gypsum Lakes.* — A short distance from our last evening's camp occur several shallow lakes, the largest a half a mile in length and about three hundred yards broad. The water of these lakes is strongly impregnated with gypsum; and the dry beds of others, situated a little further off, are thickly covered with small shining particles of selenite.

For the first few miles we traveled over slightly undulating prairie, underlaid by beds of red marly clay and white earthy carbonate of lime, the latter not unfrequently mixed with soft white gypsum, and presenting a general thickness of fifteen or twenty feet. We then came to an extensive outcrop of dark gray sub-crystalline and highly fossiliferous limestone,

which continued to exhibit itself more or less frequently during the remainder of the day's journey. This rock in a few places contains bands of soft ferruginous sandstone, and is marked by fossils of the Coal Measures, as follows: *Bellerophon Montfortianus ?* (Norwood & Prat.), *Orthis umbraculum*, *Straparollus catilloides ?*, and remains of *Crinoidea*.

Among the loose detritus I observed to-day some small fragments of soft yellow earthy Cretaceous Limestone, containing *Ostrea*.

Soil and sub-soil for the first five miles calcareous and calcareo-argillaceous; afterwards more or less silicious.

Distance, 9 miles.

Oct. 1. — Massive strata of dark gray sub-crystalline limestone of the Coal Measures were largely exhibited during the greater portion of this day's march. The rock in some places presents a thickness of nearly four hundred feet, and differs from the limestone of yesterday only in being harder and occasionally more or less cherty. The embedded fossils are usually finely preserved, and often so thickly crowded as to constitute the larger part of beds many feet in thickness. The most common species are *Athyris subtilita*, *Productus semireticulatus*, *Productus muricatus*, and *Straparollus*, *Pleurotomaria*, *Bellerophon*, and *Archæocidaris* of undescribed species.

This rock will afford an excellent building material, and, by burning, the very best of lime.

As we progress the strata are highly contorted and the surface more undulating. The hills are characterized by gentle slopes, and attain a height of from fifty to one hundred feet. Late in the day we arrived at the *Cornudas Mountain*, an isolated mass of eruptive rock, rising almost vertically to the height of six or seven hundred feet, and appearing at a little distance to be composed of materials thrown confusedly together. On every side it presents rugged and nearly vertical cliffs, some of them fissured, and exhibiting near their bases small triangular openings. The largest of these extends into the mountain nearly a hundred feet, and terminates in a spacious chamber of an irregular elliptical form, and in the center a pool of pure water. This chamber is lighted from above by means of a large triangular opening, which at the summit of the mountain terminates in an irregular basin-shaped depression, through which the water of the chamber is conducted. The pool is at present almost entirely filled with sand; but by clearing this out a sufficient supply of water might be obtained for the use of a large number of emigrants and their stock during the entire year. Besides the main chamber there are several smaller ones, all of which could very easily be rendered available for supplying water during the dry season of the year.

The Cornudas Mountain extends about one mile northeast and southwest, and its width is from a half to three-fourths of a mile. It is composed entirely of compact light gray albite granite, in which the albite predomi-

nates over the other ingredients. The mica is of a jet black color and exists in very small particles. This granite is very poorly adapted for building purposes, as it disintegrates very rapidly.

From the Cornudas the limestone presents a quaquaversal dip at angles varying from 45 to 50 degrees. Near the point of contact with the eruptive rocks it is highly metamorphosed and converted into hard cellular rock of a dusky brown color. Its visible thickness is upwards of five hundred feet, and at a little distance from the erupted mass the beds are crowded with fossils, many of them highly characteristic of the Coal Measures.

Soil, during the greater portion of the day, calcareo-silicious.

Distance, 20 miles.

Oct. 2.—After leaving the Cornudas Mountain we continued to travel over highly undulated strata of limestone of the age of the Coal Measures. The surface of the country is rolling and diversified with low rocky hills and ridges. Southwest of our road is an interrupted chain of hills of eruptive rocks, which, after connecting with the *Sierra de los Alamos*, stretch across the country for a number of miles in a southwest course.

Eight miles from the Sierra Cornudas we came to the *Sierra de los Alamos*, three rough isolated peaks, the highest of which is about eight hundred feet above the general level of the adjacent country. These, as has already been remarked, are southwest of the Sierra Cornudas, from which they differ somewhat in appearance and mineralogical composition, though they undoubtedly form a part of the same system of eruption. The rock consists of granite, gneiss, and light greenish porphyry. The granite is hard, compact, and fine textured, and graduates almost imperceptibly into the gneiss and porphyry. The latter is usually hard, and contains crystals, sometimes of quartz and sometimes feldspar. On both sides of the eruptive rocks the Upper Carboniferous Limestone is slightly metamorphosed and inclined at angles of from 10 to 30 degrees.

Beyond the Sierra de los Alamos this limestone is largely developed, and in places crowded with characteristic Carboniferous fossils.

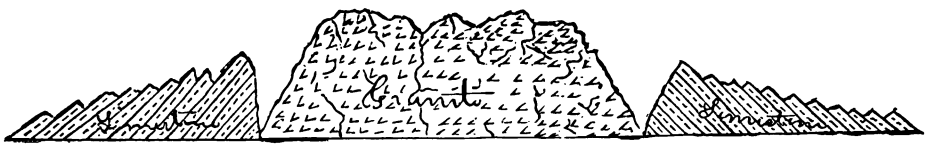
Soil and sub-soil calcareo-silicious.

Distance, 26 miles.

Oct. 3. —From the last camp to the Sierra Alto, a distance of about four miles, our road was still over undulating strata of Upper Carboniferous Limestone. The surface of the country was also marked with low hills and ridges, from the rocky sides of some of which fossils were obtained in the greatest abundance.

SIERRA ALTO.

The Sierra Alto rises majestically from a nearly quadrangular base to



Section of the Sierra Cornudas, Oct. 1, 1855.

the height of about fifteen hundred feet. It is completely isolated from the neighboring mountains, and its rugged summit projects considerably above the highest of them. Its main axis extends nearly east and west for the distance of about two miles, and its width varies from a fourth to about three-fourths of a mile. On all sides it is surrounded by hills and ridges, all of which present abrupt faces toward the mountain, and slope gradually in an opposite direction.

This mountain is composed of hard granite, of a light gray color, in which the feldspar predominates over the quartz and mica. The weathered face of the rock presents sometimes a yellow and sometimes a brown color, and occasionally exhibits a jointed structure, but more frequently a smooth and polished appearance. The surrounding hills and ridges consist of limestone and soft sandstone, which are strongly upheaved, and dip quaquaversally at angles of from 5 to 40 degrees. The layers in contact with the eruptive mass are highly metamorphosed, and of dirty brown and yellow colors. As well as could be determined from their exposed edges the thickness of the limestone and sandstone cannot here fall short of two thousand five hundred feet. As we recede from the mountain the dip of the strata becomes much less apparent, so that in the distance of a mile it does not anywhere exceed 5 or 10 degrees.

As the strata exposed at the Pass are some distance removed from the central axis of eruption they have undergone but slight metamorphic change, and are often densely crowded with fossils. Among these we recognize several species which are quite characteristic of the Coal Measures of Missouri, Illinois, and Kentucky, along with others that range downwards to the base of the Carboniferous System, but most of the species are not yet described. The list includes *Productus costatus*, *Productus Cora*, *Tellinomy protensa ?*, *Allorisma regularis*, *Bellerophon Urii*, *Bellerophon* several new species, *Straparollus* several species, *Pleurotomaria*, *Murchisonia*, *Natica*, and *Chemnitzia* several species. Most of the fossils at this locality were obtained from the debris at the base of the cliffs.

The rocks in this vicinity would afford the very best of building materials, and particularly the granite, which is of firm texture and admirably adapted for any work requiring great strength and durability.

SIERRA HUECO.

From the western extremity of the Sierra Alto our road led by a gradual descent through a broken and hilly region into a broad fertile valley, somewhat semi-circular in its form. This valley to the west and northwest opens into the "Valley of the Salt Lakes," but in every other direction it is abruptly terminated by rough hills and cliffs of limestone from five to eight hundred feet high. Its floor consists entirely of eruptive rocks, whose sharp and jagged points are seen protruding on either side, and near the

center rises the Hueco Mountain, precipitously, to the height of about six hundred feet. The mountain is divided by a broad canyon into two nearly equal portions, and on all sides are vertical cliffs, often deeply fissured from top to bottom, affording by their frowning appearance a remarkable contrast with the smooth grassy surface by which they are surrounded.

The rock composing the Sierra Hueco is a fine textured light greenish-gray granite, which is soft, and crumbles readily on exposure to the weather. It contains a much larger proportion of feldspar, and less quartz, than any of the granites we have hitherto encountered. The weathered edges present ferruginous brown and yellow colors.

"*Hueco Tanks.*"—Owing to its rapid disintegration, the granite is in places deeply excavated so as to form chambers, some of which serve as natural reservoirs, or basins, into which,* * * * * *

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Oct. 4. — "*Valley of the Salt Lakes.*"—Shortly after leaving the Hueco Mountain we entered the "Valley of the Salt Lakes," which stretches north and south several hundred miles. It is bounded on the west by the Organ and El Paso Mountains, whose sharp and jagged outlines bespeak, even at this distance, the eruptive character of the rocks composing them. On the east the valley is limited by an uninterrupted line of bold abrupt cliffs of limestone, which to the south are continuous with the bluffs in the vicinity of the Hueco Mountains, while in the opposite direction they extend for a distance of forty or fifty miles, and terminate in the Sacramento Mountains, which rise majestically to an altitude of several thousand feet.

A little west of this line of cliffs, and running parallel with them, is a chain of sharp ridges and conical hills which connect with the Sierra Hueco, and possess, as far as examined, the same structure, being composed of fine textured gray granite. The valley at the point of entrance is about twenty-five miles wide, and has a smooth, even surface, covered for the most part with short grass. After entering it our road during the remainder of the day was over coarse reddish sand and detritus of eruptive rocks.

Distance, 16 miles.

Oct. 5.—*El Paso Mountains.*—After traveling twelve miles farther, over extensive deposits of sand and detritus, we reached the southern extremity of the El Paso Mountains, around which our road led by a gradual descent into the valley of the Rio Grande. These mountains form a continuous chain about thirty miles in length, extending, as already intimated, in a north and south direction, and although bearing a different name constitute merely a detached portion of the Organ range, from which they are separated on the north by a smooth valley from a fourth to a half a mile wide.

To the south they terminate abruptly to form "*The Pass*," beyond wh the lofty summits of the same range are again seen stretching southw for many miles. Viewed from the east, they rise abruptly from a smoo and gently ascending plain, attaining at the highest points an elevation about two thousand five hundred feet. Their summits are generally sha and jagged, and to the north they rise in succession, one above the oth like the pipes of an organ; hence the name of Organ Mountains, which h been applied to the entire range.

As will be shown hereafter, they vary considerably in composition. Th southern portion consists of hard granite and porphyry. The granit greatly predominates over the porphyry, and varies in color from ligh gray to deep vermilion. It is sometimes more or less porphyritic, and it hardness and durability would render it an excellent building materia The porphyry is confined chiefly to the summits. Usually it is of a dee red color, and contains crystals of quartz and sometimes of feldspar. Near the western base of the mountains fragments of dark colored scoria were frequently observed.

Against the western declivity of the mountains the limestone strata are strongly upheaved, and where it is in immediate contact with the eruptive rocks, is highly metamorphosed. I was much interested in finding here, near the base of the exposure, well marked strata of the Inferior Silurian System, corresponding in age to the Blue Limestone of Cincinnati and the Hudson River Group of the New York Series. The following fossils were procured from these beds: *Orthis testudinaria* (Dalman), *Orthis occidentalis* (Hall), *Rhynchonella capax* (Conrad), *Rhynchonella* (a species of the Blue Limestone of Cincinnati), *Streptelasma cornicula* (Hall), and columns of Crinoids.

In following the windings of "*The Pass*" we first descended over thick deposits of loose and partially consolidated detritus, after which nothing was encountered but granite and limestone. The surface is generally hilly, and slopes toward the Rio Grande, which is here of moderate depth and flows over a rocky bed.

From this point to Dona Ana the course to be pursued by the Expedition is nearly north.

Distance traveled during the day, 20½ miles.

Oct. 7.—Our route this day was along the valley of the Rio Grande, which varies greatly in width, and is characterized by dark rich alluvial soil, bearing a luxuriant vegetation. From the east the surface presents a gradual slope towards the Rio Grande, and the western border is marked, for the first few miles above El Paso, by rugged mountains of granite and porphyry, and afterwards by precipitous bluffs which form the eastern edge of an elevated *Mesa*. I observed again to-day the soil frequently encrusted with efflorescences of common salt and soda. The river presents an aver-

cent width of about one hundred yards, the water is moderately deep and hurnly charged with fine yellow sediment.

equ'he El Paso Mountains exhibit the same general appearance and mineratopical composition as described yesterday. The limestone of the Lower conurian System is seen strongly upheaved against the western base, until reach a point about ten or eleven miles north of the place it was first discovered, where it disappears, and is succeeded by strata of the Carboniferous western, which are exposed in places to the thickness of about three hundred thet.

Black ferruginous sand was observed in several localities near the base of e mountains, and the indications are such as to lead to the belief that this pgion may be found rich in valuable metals.

Distance, 16 miles.

Oct. 8.—With the exception of being wider the portion of the valley of the Rio Grande traveled over to-day does not differ in general appearance from that of yesterday. The soil continues rich and clothed with luxuriant vegetation. East of our road the surface of the country ascends gradually towards the base of the mountains (estimated now to be about ten miles distant). It is for the most part covered with a thick accumulation of coarse red sand, with fragments of limestone and eruptive rocks embedded. Between our road and the mountains there occurs several uneven hillocks of hard gray porphyry, containing crystals of light gray feldspar. They are from thirty to sixty feet high.

The mountains for the first fifteen miles present the same character as before, but after passing the "*Puerto del Bracito*" they change in appearance and structure, and consist chiefly of highly inclined strata of dark blue and gray Carboniferous Limestone, dipping west, and presenting precipitously to the east. The thickness of the limestone, as shown here by its exposed edges, is about three thousand feet In a couple of miles the limestone disappears, and is succeeded by eruptive rocks of the same character as before.*

From Fort Fillmore to Dona Ana, a distance of about fourteen miles, our road was principally over alluvium and coarse detritus. East of us the surface is rough, much cut up by ravines, and still exhibits a gradual ascent towards the mountains. At a locality about three miles east of *Las Cruces* the Carboniferous Limestone is exposed to the thickness of about six hundred feet. In places the strata are crowded with encrinite stems and other fossils.

*For a further description of the rocks of this locality, see notes of March 8th, 1856, Chapter VIII.

CHAPTER VII.

RECONNOISANCE WEST OF THE RIO GRANDE. — FROM FORT FILLMORE TO THE VALLEY OF THE MIMBRES, NEW MEXICO.

The reconnoisance of which the following is a report was ordered principally with a view to the determination of the practicability of obtaining water by means of Artesian Wells from the elevated and arid region situated between the Rio Grande and Mimbres Valleys. This has already been made the subject of a special report, but inasmuch as many of the facts collected were omitted in that report as foreign to the subject then under consideration, and as they may have an important bearing upon the question of a Pacific Railroad, besides being of general scientific interest, it is thought advisable to give the results of the exploration in detail.

In this excursion I was accompanied by a topographer and a small escort of mounted soldiers. We started from our camp near Fort Fillmore on the morning of the 15th of October, and shortly afterwards forded the Rio Grande, which is here about one hundred yards wide, of moderate depth, and flows between low bluff banks of yellow loam. Its bed is composed principally of quicksand, and the water is highly charged with fine yellow sediment, but it possesses an agreeable and somewhat alkaline taste. On either side the land is flat and covered with rich soil, bearing a heavy growth of timber, principally cottonwood.

Taking a northwest course we traveled for several hours over thick alluvial deposits of fine yellow micaceous sand and sandy clay. The river valley here is from three to six miles wide, with a gentle slope from the east to the river, but abruptly terminated in the opposite direction by a range of bluffs varying from two to four hundred feet in height. These serve to mark the eastern border of an elevated mesa or table land, and are composed chiefly of coarse red silicious and feldspathic sand, with irregular seams of clay and fragments of porphyry, basalt, greenstone, and other eruptive rocks disseminated through it. Here and there occur hills and low terraces of fine, light yellow, silicious sand, and the surface is at some points covered with a saline efflorescence. The soil is deep and usually well adapted for cultivation. It is capable of yielding corn, wheat, barley, and other agricultural products in plentiful crops, but owing to the dryness of the climate requires frequent irrigation. This is in general very readily accomplished by means of irrigating canals, which traverse the valley in all directions, and are so arranged as to spread their contents over the surface whenever required.

As we continued on our route the surface assumed a broken and hilly aspect. At the distance of ten miles we reached the "*Picacho*," a sharp

conical peak rising abruptly to the height of eight hundred and fifty feet. It forms the most elevated part of a broad dyke that extends somewhat irregularly, with a W. S. W. bearing, from the Dona Ana Mountains, a distance of about fifteen miles. To the east this protrusion exhibits an average width of five or six miles, but rises above the surface only at a few points in the form of low rounded hills and ridges. After having been partially cut through by the valley of the Rio Grande it is again seen rising near the eastern base of the Robledo Mountains to the height of several hundred feet, attaining its greatest elevation at the "*Picacho*," whence it again diminishes in height and for a time disappears beneath the detrital deposits of the mesa.

It is composed principally of dark red and slate colored porphyry, greenstone, and claystone. The porphyry is soft, yields rapidly to the weather, and near the "*Picacho*" is thickly reticulated with veins of fibrous gypsum. From this point the sedimentary strata dip towards the mesa at an angle of about 16 degrees, being highly metamorphosed and partially converted into schist.

Immediately north of the "*Picacho*" is the Robledo Mountain, presenting abruptly to the river. It is a bold, rugged escarpment, about one thousand feet in height, and, as far as examined, consists of hard gray and blue crystalline limestone of the Carboniferous System. Among the species collected from this locality were *Productus costatus*, *Athyris subtilita*, and *Pleurotomaria*, *Chemnitzia*, and *Straparollus* of undescribed species. The strata dip southwest at an angle of about 16 degrees.

After leaving the "*Picacho*" we traveled in a westerly course over a rough and hilly district, composed for the first mile or so of eruptive rocks of the same character as above mentioned; afterwards we encountered light gray limestone and metamorphosed argillaceous shale. The limestone is for the most part hard semi-crystalline, and although occasionally much divided and upheaved by the protrusion of basaltic dykes, appears to have undergone but slight metamorphic change, as it is replete with well preserved examples of *Productus costatus*, *Athyris subtilita*, and other Carboniferous fossils. The inclination of the strata is S. S. W. 25 degrees. Their exposed edges show a thickness of over six hundred feet.

North of our route the country is everywhere rough and mountainous, but south the eye encounters a smooth grassy surface (mesa), with a gentle slope towards the river valley, here and there interrupted by low ridges and abrupt conoidal hills, which are grouped together in clusters of six or eight. From their general broken outline there can scarcely be a doubt that the rocks composing them are of the eruptive class.

As we advanced the strata became highly undulated and folded, finally assuming a marked metamorphosed character, the limestone being altered in color and texture and devoid of any traces of organic remains.

Valley of the "Boundary Station."—Nine miles from the "*Picacho*" ed came to the valley of the "Boundary Station," which is about fifteen mi wide, and bounded on either side by abrupt escarpments of upheaved sea, mentary strata. d

This valley extends many miles northward, but to the south is limited by chains of hills and ridges several hundred feet high. Its floor is com posed of eruptive rocks, which are traversed by nearly parallel dykes of hard red and purple porphyry, basalt, and vesicular amygdaloid. One of these dykes rises abruptly above the general surface as high as six hundred feet, forming what is denominated the Boundary Station.

The elevations composing the southern boundary of the valley consist of eruptive rocks, from which other dykes extend in low but apparently continuous ridges across the mesa to within a short distance of its southern boundary, where they connect with the igneous ranges already mentioned. The surface of the valley is generally smooth, and thickly covered with coarse reddish feldspar and quartz sand, with chalcedony, agates, and cornelians disseminated through it. I also observed black iron sand in several localities, and it is not improbable that this district as well as that farther west may prove to be auriferous.

The abrupt edges of the strata constituting the western boundary of the valley are terraced, and as they extend northward attain the height of over a thousand feet; but not having time to examine them I was unable to determine their precise character.

Ascending from the valley of the Boundary Station we pursued a westerly direction over an elevated plateau with gentle slopes, and composed principally of highly metamorphosed sedimentary strata, the continuity of which is frequently interrupted by dykes from a hundred yards to a mile wide, and which extend somewhat irregulary across the plateau, with a north and south bearing. Our road was crossed by no less than sixteen of these dykes. They differ but slightly in lithological character from those previously examined.

This plateau is about twenty miles broad. It is covered with coarse red sand, fragments of decomposing limestone, and eruptive rocks. The soil is usually fertile, and clothed with short grass. If means could be provided for a supply of water during the dry seasons of the year, it would prove highly productive. Upon its western side the plateau terminates abruptly in a long line of bold and precipitous escarpments, in places upward of five hundred feet high. These exhibit near their bases rude projecting masses of dark red and purple porphyry and other varieties of eruptive rocks. To the south they decline gradually toward the mesa, and finally disappear entirely, while the igneous protrusion still continues above the surface in low gently rounded hills, with a general bearing south 10 degrees east. The strata composing the escarpment dip 20 degrees E. S. E.,

cord they are usually so highly metamorphosed as to be hardly distinguishable from igneous rock.

For the next thirteen and a half miles in the direction of the *Picacho de los Mimbres* our road led over compact purplish porphyry, amygdaloid, and basalt, traversed by occasional dykes and veins of greenstone, quartz, and chalcedony. The surface of the country exhibits a gentle slope to the east, and is covered with a deposit of coarse red silicious and feldspathic sand and detritus from ten to a hundred feet in thickness, and containing at its upper portion agates, cornelians, and pebbles of chalcedony Black ferruginous sand was frequently observed along our route, resembling so closely the auriferous sand of California as to induce the belief that gold may be found in this region. Specimens of this sand have been subsequently examined chemically, but no traces of gold were detected in it.

The Mimbres Mountains near the southern extremity are characterized by a number of rugged conoidal peaks, the highest of which constitutes the "*Picacho de los Mimbres.*" It is elevated probably twenty-five hundred feet above the level of the adjacent valleys. The main axis of the Mimbres Mountains runs north 42 degrees west. As far as examined the range consists of a very compact purple porphyritic granite, containing a large proportion of quartz and a deficiency of mica. On either side occur dykes of greenstone, red and dark porphyry, and amygdaloid. Between two of these, and near the base of the eastern slope, a small stream of water known as Cook's Springs gushes forth, which is constant during the year. The water is clear, slightly alkaline, and possesses a temperature of 60 degrees F. It is contained in irregular basin-shaped depressions scooped out of the porphyry. No sedimentary rocks were anywhere observed in the neighborhood. Upon the western side of the mountains thermal springs are said to occur, but I was not able to visit this locality.

From near the eastern base of the mountains, and several miles north of the southern extremity, a broad dyke rises to the height of six or eight hundred feet, bearing south 12 degrees west. It extends a distance of twenty-five miles, and intersects the *Sierra Florida* near its southern extremity. This dyke consists of compact red porphyry, greenstone, quartz, and amygdaloid. The extremities only are seen projecting above the surface, its central portion having apparently been removed by erosion.

After leaving the *Picacho de los Mimbres* we traveled in a southerly direction over continuous beds of igneous rocks. The surface of the country is for the most part hilly, and thickly strewn with coarse angular fragments of granite, porphyry, quartz, and amygdaloid. The mountains, after attaining their greatest elevation at the *Picacho*, descend rapidly towards the south, and at the distance of about nine miles terminate in a broad open plain, which connects on the one hand with the valley of the Mimbres and on the other with the mesa. This plain presents on both sides a

gentle slope towards the middle, and is thickly covered with coarse red sand and fragments of igneous rock.

Early on the morning of the 19th inst. we arrived at the *Sierra Florida*, a short detached range which rises abruptly from a gently undulating and ascending plain, and like the Mimbres range, presents a number of rugged peaks. The highest of these attain an elevation above the base of near two thousand feet. The direction of the main axis or line of eruption is north 55 degrees west. The rocks are compact trachyte porphyry and cellular quartz, both of which appear to be yielding rapidly to the weather, and present externally a dirty ferruginous brown color. Black iron sand occurs in great abundance in the neighborhood, and among the loose detritus near the base of the mountains some fine agates and cornelians were collected.

From the summit of the *Sierra Florida* a good view may be had of the valley of the Mimbres, which stretches many miles to the west, and is surrounded on all sides by rugged mountain chains, whose sharp and jagged peaks seem in the distance to rise one above the other in almost endless succession, while through the center of the valley long lines of low sombre looking hills and ridges indicate the existence of numerous dykes. In fact the whole of the valley appears to have been the theater of intense igneous action, and no evidence of the existence of sedimentary strata are anywhere visible upon the surface. Its floor, as far as we were able to judge from a distance, appears to be composed of coarse red sand and detritus, generally thinly covered with short moss-like grass.

Having completed our examination as far west as the valley of the Mimbres, and determined pretty accurately the geological character of the east, north, and west boundaries of the district we were directed to explore, our attention was next directed to the central and southern portions of the mesa. This presents throughout the greater portion of its extent a gentle slope towards the valley of the Rio Grande, and consists chiefly of thick deposits of coarse silicious and feldspathic sand, with fragments of eruptive rocks disseminated through it. The land is covered with short grass, and is here and there diversified with hills and low ridges, which are arranged in nearly parallel lines, and are nothing more than the projecting portions of dykes, chiefly of dark compact basalt and porphyry. A few miles south of the Boundary Station the hills rise abruptly to the height of several hundred feet, presenting a dark and exceedingly rugged aspect.

On the south side the mesa is bounded by a range of detached hills, which extend from near the valley of the Rio Grande to within a short distance of the *Sierra Florida*. These hills appear to be from two to six hundred feet high, and consist of igneous rocks of a dark and very rough appearance. To the south they appear to connect with others, which, as we shall hereafter see, are of quite recent origin.

As we approached the valley of the Rio Grande the surface became

rough and here and there traversed by deep ravines. From some of these, sections of the Quaternary beds were obtained three or four hundred feet high, but they do not in general differ from those exposed along the river valley.

Having again reached the valley of the Rio Grande, we traveled south 32.5 degrees east. At the distance of five miles we came to a heavy deposit of black basaltic lava, projecting abruptly above the surface to the height of a hundred and twenty-one feet, with an average width of about a mile. This is composed near its base of heavy compact basalt with a vitreous luster, containing small green particles of chrysolite; but as we approached the summit of the lava stream it gradually assumes the character of a vesicular basalt, and finally that of highly vitreous scoria. This stream is about two miles long, and appears to have proceeded northeast from an abrupt truncated cone known as the *Picacho de las Mesa*. Its surface is for the most part flat, totally devoid of vegetation, and seems to have undergone but little or no alteration since the period of its eruption. On nearly every side it terminates abruptly.

The "*Picacho*" is also composed of lava, and projects above the lava stream at its base to the height of about two hundred feet. At the summit is a shallow basin-shaped depression, near the center of which an artificial excavation has been made to the depth of about twelve feet. Here the scoria is light, friable, and resembles highly burnt cinder.

Ten miles south of the "*Picacho*" is a second cone, about six hundred feet high, from which a broad sheet of lava proceeds in an easterly course for the distance of about ten miles, where it terminates abruptly. This stream, as well as could be determined at a distance, has an average breadth of about two and a half miles, and does not differ in general appearance from that of the "*Picacho*."

From the character and general appearance of these cones and lava streams, I am disposed to ascribe their origin to a comparatively recent geological period. They form a part of an extensive volcanic chain, which may be traced north and south for several hundred miles.

CHAPTER VIII.

FROM DONA ANA, NEW MEXICO, TO THE HUECO MOUNTAIN, VIA SAN AUGUSTINE PASS.

The Expedition having been again ordered to the Rio Pecos, it was determined, in order to save time, to adopt the shorter and more direct route, by way of San Augustine Pass, and from thence intersect our former route at the Hueco Pass. As the geology of this region is comparatively but little known, the following observations, taken between Dona Ana and the Hueco Mountains, may be of some interest:

Mar. 8, 1856. — After leaving Dona Ana we gradually ascended for several miles over thick deposits of coarse red silicious and feldspathic sand, and angular fragments of porphyry, granite, and other eruptive rocks. The surface is everywhere rough and hilly, and often traversed by long narrow ravines.

Vegetation is sparse, and consists chiefly of coarse bunch grass and mezquite bushes.

At the distance of about three miles we reached the Dona Ana Mound, a solitary peak, which rises to the height of about six hundred feet, and constitutes the most southerly part of the Dona Ana Mountains. Like those farther north, it is composed of a variety of eruptive rocks, mostly of purple and slate colors, and although separated from the main range by a valley several miles in width, it is no doubt contemporaneous with it.

Passing this Mound we entered the *Jornada del Muerto* at the southern extremity. Its width here is about twelve miles, but northward it is much broader. To the east it is abruptly terminated by the Organ Mountains. The surface is generally smooth, and thinly covered with short moss-like grass. In crossing it our road for the first six miles was by a gradual descent, over heavy deposits of coarse red sand and fragments of igneous rocks. Beyond this the surface is in places thickly strewn with small angular fragments of hard gray and blue crystalline limestone, with *Productus spirifer*, spines of *Encrinites*, and other Carboniferous fossils. After traveling fifteen miles we reached the western declivity of the Organ Mountains, and soon after entered the San Augustine Pass, through which we continued to travel the remainder of the day. Directly south of this pass the mountains attain an elevation of about three thousand feet. Their outline is sharp and jagged, and the peaks project above each other in rapid succession, giving to the mountains a highly picturesque appearance. Here they are composed almost entirely of compact red porphyry and light gray porphyritic granite, in which feldspar greatly predominates. The porphyry

was only observed on the western side of the mountains, and forms but an inconsiderable portion of the range.

Against the western declivity the Carboniferous Limestone is exhibited, dipping about 80 degrees west, and where it is in immediate contact with the eruptive mass presents a highly metamorphosed appearance. A short distance from the mountains it is compact sub-crystalline, of a dark bluish and gray, and crowded with fossils. In many places the rock is thickly reticulated with veins of quartz, porphyry, calc, and fluor spar, some of which present indications of being metaliferous. It is in the limestone of this neighborhood that the rich mines of argentiferous galena, at present little known but destined ere long to be extensively and profitably worked, have been discovered. Magnetic iron ore of a very fair quality also occurs in this vicinity.

Our way through the Pass led mostly over hard porphyritic granite similar to that last described. This rock forms on either side of the Pass rough and in places almost vertical cliffs from one to two thousand feet high. But a little farther north it diminishes rapidly in elevation, and at a distance of one or two miles we find it merely in detached hills a few hundred feet high, and at the same time the Carboniferous Limestone becomes largely developed, and soon constitutes by far the greater portion of the entire bulk of the mountains.

Mar. 9.—This day we traveled for several hours through the Pass, and then emerged into a smooth open plain, extending north and south as far as the eye could reach, and having an average width of about thirty miles. On our road to El Paso we crossed this plain about forty miles farther south. It presents the same general features here as in its southern extension. North of us the surface is frequently whitened with saline incrustations and marls.

On either side it is enclosed by lofty mountains. Those on the east—the Sacramento range—appear as a continuous line of bold, rugged, and nearly vertical escarpments, extending many miles north, the most prominent peak being the snow clad summit of the *Sierra Blanco*, from which they decline in elevation both north and south. In the neighborhood of the Dog Canyon they do not appear to exceed eight hundred or a thousand feet in height.

Immediately to the west of the Sacramento Mountains, and pursuing a course nearly parallel with them, occur the range of eruptive rocks already mentioned as forming a continuation of the Hueco Mountains. Opposite the mouth of the Dog Canyon they form a ridge several miles in length with an elevation of seven or eight hundred feet, and thence northward they diminish in height and are exhibited merely in isolated points for the distance of forty or fifty miles.

After entering the plain we travelled along the eastern base of the Organ Mountains, which here present an exceedingly rugged appearance, but with

the exception of being occasionally of a deep red hue, the rocks forming them do not differ from those last described. Our road was mostly over hornblende and mica schist, in many places thickly traversed with dykes of quartz, greenstone, and porphyry, often appearing in low isolated hills and ridges several miles east of the mountains. All of these rocks yield rapidly to the weather, and the surface is generally thickly covered with coarse red sand in which feldspar is freely mingled.

Late in the day we arrived at the *Ojo de la Soledad*, a clear stream of running water one or two feet deep, which originates from springs that issue from the igneous rocks. The water is clear, highly alkaline, and possesses a temperature of about 68 degrees F.

Mar. 10.—I spent the greater portion of this day in exploring the mountains near the *Ojo de la Soledad.*

They here present an exceedingly rough aspect, and are traversed from east to west by deep, tortuous canyons, some of them with nearly vertical walls from a thousand to fifteen hundred feet high. These were found to consist mainly of coarse granite in which feldspar predominates. The color varies from light gray to brown and deep red; the mica is usually black and in very minute scales, while the quartz is often so intimately blended with the feldspar as to render it difficult to distinguish one from the other. The altitude of the mountains at this point is from two to three thousand feet, and their summits exhibit a remarkably sharp and broken outline.

A few miles south the eruptive rocks decrease rapidly in elevation, and are finally succeeded by upheaved strata of hard crystalline limestone of the Carboniferous Period, which increases rapidly in thickness and soon constitutes almost the entire bulk of the mountains. This rock presents precipitously to the east, where it exhibits a thickness of about three thousand feet, with a dip to the west at angles of from 30 to 60 degrees. It is usually compact, of dark blue and gray colors, with bands of dark argillaceous shale intercalated, from thirty to a hundred feet thick.

Many of the layers are rich in fossils, and some of them are almost entirely made up of the remains of *Crinoidea.* Among the fossils collected from this locality are *Productus semireticulatus*, *Productus* several undescribed species, *Spirifer Forbesii*, *Spirifer lineatus*, *Spirigera hirsuta*, *Terebratula subtilita*, *Terebratula lamellosa*, *Orthis umbraculum*, and *Phillipsia Merimacensis.* The sedimentary strata extend as far as the "*Puerto del Bracito,*" and are then again succeeded by the eruptive rocks, which continue all the way to El Paso.

From the evidence collected I am inclined to the opinion that the valley between the Organ and Sacramento Mountains is mainly, if not entirely, composed of eruptive and metamorphic rocks.

Mar. 11.—After leaving the *Ojo de la Soledad* we continued our southerly

course along the eastern base of the mountains for eight or ten miles, over mica and hornblende schist, with occasional intrusions of quartz, porphyry, and other eruptive rocks. We then diverged towards the Hueco Mountains, now plainly visible and about forty miles distant. Beyond the mountains the surface of the country gradually descends for three or four miles, and is often covered with coarse angular fragments of eruptive rocks. At the distance of six miles we reached a range of low gently sloping hills of red porphyry, quartz, and other eruptive rocks; the porphyry being in some places so soft as to admit of being crushed between the fingers. Passing these hills we continued during the remainder of the day over thick beds of coarse sand, with fragments of decomposing igneous rocks intermingled. The surface is for the most part flat, and covered with short bunch grass, and the soil generally of the most unproductive character.

Mar. 12. — During the entire day's journey we continued to travel over coarse red sand and detritus of the same character as before. The surface is in many places slightly undulating, and the soil generally barren, supporting only a sparse growth of coarse bunch grass. No limestone or any other sedimentary rocks were anywhere observed on the road.

Mar. 13. — Shortly after leaving camp to-day the surface became much more hilly, but still thickly covered with coarse sand and detritus of the same character as above. At the distance of five miles we arrived at a series of low rounded hills of dark bluish and gray crystalline limestone, dipping east and southeast at angles of from 30 to 70 degrees, and highly charged with fossils of the Coal Measures. These hills connect towards the southeast with the line of cliffs already described as forming the southern prolongation of the Sacrameto range, and the upheaval of the strata is doubtless due to the protrusion of the Hueco Mountains. Shortly after passing these hills we reached the Hueco Mountains and entered upon our old road from the Rio Pecos. During the latter portion of our day's march the soil was found to improve in character, and in some places was covered with a thick growth of grass.

CHAPTER IX.

FROM THE HORSE HEAD CROSSING OF THE RIO PECOS TO SAN ANTONIO DE BEXAR, VIA FORT MCKAVITT, FORT MASON, AND FREDERICKSBURG.

From our permanent camp near the mouth of Delaware Creek to the Horse Head Crossing of the Rio Pecos our route was over nearly the same region as that traversed by the Expedition from May 19 to May 26, 1855. I shall, therefore, in the present chapter, only speak of the geology of that portion of our return route east of the Horse Head Crossing.

At this crossing the Rio Pecos makes an extensive bend to the southeast, and presents on both sides low bluff banks of red marly clay. The valley on either side is broad, moderately fertile, and in places covered with a growth of excellent grass.

After leaving the river we at first passed over red clay and sandstone, and at three miles ascended to the summit of a low mesa, and soon after encountered thick beds of snow white gypsum and pulverulent limestone, reposing upon the clay and sandstone. The surface of this mesa is generally moderately undulating and thickly covered with grass and mezquite bushes. In several places it is strewn with small angular fragments of dark scoria.

After traveling thirteen and a half miles we arrived at the "Castle Mountains," which stretch irregularly north and south for many miles, and are nothing more than the borders of the table land terminating percipitously to the west. They are a continuation of the same cliffs encountered by the Expedition while *en route* from San Antonio to El Paso. (*See notes of May 18, 1855, Chapter IV.*) At this point their height above the valley of the Pecos is about eight hundred feet, but they decline gradually towards the north, so that in fifteen or twenty miles they do not exceed two hundred feet in height. In their southern extension they also decrease in elevation, and at the distance of forty miles curve gently to the west. They consist of red clay surmounted with limestone of the Cretaceous System. (*See section No.* —.) The thickness of the limestone at the point examined is about seven hundred feet. It is in some places compact, crystalline, and of a light gray color, and in others soft, earthy, and disintegrates rapidly. The usual Cretaceous fossils were observed in it in the greatest abundance, limited, as at many other points farther south, chiefly to two distinct bands near the top and base of the formation. The upper band is about one hundred feet thick, of a light yellow color, earthy in texture, and is undergoing rapid disintegration. The lower band is about fifty feet thick, and is compact and subcrystalline. From the upper band I collected examples of *Cardium Sancti-Sabæ*, *Janira Texana*, *Hemiaster elegans*, and *Pterodonta subfusiformis.*

The clay is highly indurated and of a deep red color. Near its upper

portion thin seams of saccharoid and transparent gypsum are interstratified. The dip is E. S. E. about 1 degree.

On reaching the summit of the cliffs we found ourselves upon a gently rolling country, thickly covered with grass and mezquite bushes, stretching eastward to the verge of the horizon. South of our line of travel is a still more elevated plateau, limited by a continuous line of bold rugged cliffs of compact Cretaceous Limestone from two to three hundred feet high. The surface of this plateau is also gently rolling, and here and there interrupted by canyons, some of them with steep declivities several hundred feet deep.

Distance from the Horse Head Crossing of the Rio Pecos to our evening camp, 21¼ miles.

Sept. 7.—Our road during this day was over an elevated and gently undulating plateau, with a dark marly soil, supporting in many places a thick growth of grass and mezquite bushes and exhibiting frequent exposures of the Cretaceous Limestone. After traveling twelve miles we reached the Wild China Ponds, a series of shallow basins hollowed out of the limestone.

These are natural reservoirs for water, which may be obtained here several months after the close of the rainy season. From this point to Flat Rock Ponds, situated about fourteen and a half miles distant, there is but little variety of surface, our road being still over gently undulating country.

Distance, 26½ miles.

Sept. 8.—After leaving Flat Rock Ponds our route was still over elevated prairie, differing but slightly in its geological features from that of yesterday. The Cretaceous Limestone is still the prevailing formation, appearing above the general surface in smooth and gently rounded hills from fifty to two hundred feet high. The country is thickly covered with dark marly soil, more fertile than any previously encountered, and its aspect more pleasing. It bears a heavy growth of grass and mezquite trees.

At about twelve miles we came to a series of shallow basins partially filled with rain water, similar to those encountered yesterday. A farther travel of twelve miles and a half brought us to the head of the Rio Concho. This stream rises in a swampy valley, whose direction is somewhat irregularly east and west. It is limited on either side by long low ridges of Cretaceous Limestone. The bed of the stream has an average width of about twenty feet, and on both sides are steep rocky banks.

Distance, 24½ miles.

Sept. 9.—This day our route lay through the valley of the Rio Concho, which increases rapidly in width as we advance. It is characterized by rich dark soil, bearing an abundant vegetation, and bounded on either side by a plateau from two to three hundred feet high, with gentle declivities down to the level of the valley. These plateaux are traversed by deep

valleys, some of them two or three miles wide, and bearing pretty nearly east and west.

The river draws its supply of water mainly from springs. A few miles below the source its average width is about seventy-five feet; its banks are precipitous, and usually skirted with dense vegetation. The Cretaceous Limestone still prevails in nearly horizontal strata, and abounds with fossils.

Distance, 17½ miles.

Sept. 10.—Our road still continues along the valley of the Concho, which varies from a few hundred yards to several miles in width, and is thickly covered with a dark and remarkably fertile soil. The surface is diversified with rounded hills of Cretaceous Limestone from one to five hundred feet high. At one locality near the river margin the red marly clay and sandstone were also exhibited, as shown in the following section:

1. Hard gray Cretaceous Limestone. 500 feet.
2. Indurated deep red clay. 20 feet.
3. Soft, ferruginous, coarse grained sandstone, crumbling rapidly to the weather. 50 feet.

Sept. 11.—Geological formation the same as before. Our road during the day was mostly over gently rounded hills from two to four hundred feet high, separated by deep valleys. The limestone composing the floors of the valleys is usually quite soft, disintegrates readily, and is in places filled with Cretaceous fossils.

Soil rich and in places supporting a heavy vegetation.

Trees, mostly mezquite, live oak, wild china, hackberry, and pecan.

During the day's march we crossed several tributaries of the Rio Concho, all of which rise from springs, the water of which is highly charged with calcareous matter.

Distance, 14 miles.

Sept. 12.—The general features and geology of the country seen to-day are the same as yesterday. In the declivities of the hills the strata are exposed often to the height of four or five hundred feet, and occasionally are crowded with fossils, of which the most common are *Ammonites acuto-carinatus*, *Cardium multistriatum*, and *Homomya alta*.

After traveling eleven miles we arrived at one of the principal affluents of the Rio Concho. This is here about seventy-five feet wide, and flows between bluffs and well wooded banks. The water is clear, calcareous, and its average depth about five feet.

Distance, 18¾ miles.

Sept. 13. — After traveling eleven and a half miles farther through the valley of the Rio Concho we ascended to the top of the table land, over which we continued the remainder of the day. At the point of ascent the Cretaceous Limestone is well exposed, and exhibits a thickness of about five hundred feet. The strata vary considerably in compactness and color, and contain bands of chert and rounded nodules of dark flint. Characteristic fossils of the Cretaceous System occur here in great abundance. The suface of the table land is usually flat, and occasionally rocky, but more generally thickly covered with dark rich soil, supporting a fine growth of grass.

Distance, 19¾ miles.

Sept. 14.—Shortly after leaving camp we entered into the broad and fertile valley of the Rio San Saba near its head. This stream rises from a number of shallow pools which derive their supply of water from springs in the vicinity. The water is clear, highly calcareous, and has a temperature of 69 degrees F. The surface of the valley is diversified with gently sloping ridges and rounded hills from one to four hundred feet high, and composed of Cretaceous Limestone in nearly horizontal strata.

At the distance of twenty-two miles from our camp we came to Fort McKavitt, situated upon a rocky hill near the river. It is surrounded on all sides by fertile valleys. At this point the Rio San Saba is about sixty feet wide, flows over a rocky bed, and is bounded on either side by abrupt walls of limestone. The whole district traversed to-day is a desirable one to the agriculturist, and destined at no very distant period to be thickly inhabited.

Distance, about 25 miles.

Sept. 15.—After leaving Fort McKavitt we traveled for several miles over nearly flat prairie, with dark carbonaceous soil, supporting a thick growth of grass and mezquite. The country then becomes hilly, and was traversed from east to west by long low ridges, with precipitous sides, and composed of gray and light yellow earthy Cretaceous Limestone in nearly horizontal layers. During the day we frequently crossed the Rio San Saba, which is a beautiful clear stream with a hard rocky bed. Its width is from fifty to one hundred feet, and on either side are escarpments of limestone exposed sometimes upwards of a hundred and fifty feet high. The river valley is from a half to three or four miles wide. In places it is thickly strewn with rounded flints and coarse angular fragments of limestone.

Distance, 25 miles.

Sept. 16.—After leaving camp we passed over strata of hard gray limestone, with an abundance of flint nodules embedded, and containing but few fossils. Below these we have soft earthy yellow limestone, densely crowded with organic remains, the most abundant species being *Exogyra Texana*,

Natica elevata, *Actæonella dolium*, *Lima Wacoensis*, *Cardium Hillanum*, and *Pterodonta subfusiformis*.

These beds have a thickness of about eight hundred feet, and dip west 8 degrees. They prevail for about five miles, and are then succeeded by heavy deposits of red marly clay and sandstone, which emerge from beneath the limestone, exhibiting a thickness estimated at from five to eight hundred feet. The clay is highly indurated, of a bright vermilion color, and interstratified with the sandstone. In lithological character it is not to be distinguished from that in the vicinity of the Rio Pecos.

After traveling a mile over this formation we came to an extensive outcrop of hard gray granular limestone, belonging to the Upper Division of the Carboniferous System, which here is to be seen emerging from beneath the Cretaceous strata. These rocks are exposed for the distance of about five miles, and form an anticlinal axis from which the strata dip east and west at an angle of about 10 degrees.

I found here characteristic Carboniferous fossils in great profusion. The most common species are *Terebratula subtilita*, *Spirifer Meusebachanus*, *S. lineatus*, *Fenestella* species undetermined, *Productus punctatus*, *P. costatus*, and *P. æquicostatus*.

Beyond this exposure the Cretaceous strata again appear, and continued to be exposed at frequent intervals until we reached our evening camp.

The country passed over to-day is rolling and the soil rich.

Distance, 15 miles.

Sept. 17.—Gray and yellow earthy Cretaceous Limestone was largely developed for several miles along our route to-day, to which succeeded strata of red marly clay and soft sandstone. At the distance of eight miles we found thick layers of coarse quartzose sandstone, which differ in a marked manner from any previously encountered. It is micaceous, of deep red and black colors, hard, and passes into conglomerate. Its thickness is estimated at about six hundred feet, and the dip is west at angles of from 10 to 20 degrees. About three miles beyond this point the same beds are highly contorted and metamorphosed, and are seen reposing on granite.

From this locality to within a short distance of Fort Mason our road was almost entirely over coarse reddish granite, gneiss, and mica schist. In places the granite projects above the surface to the height of two or three hundred feet, imparting to the country a peculiarly rough and sterile appearance. This range bears nearly north and south, and may be traced a great many miles in either direction.

At Fort Mason the sandstone is again well developed, presenting in abrupt hills five or six hundred feet high. The strata are here highly undulated, and dip in various directions at angles of from 20 to 50 degrees. A short distance beyond Fort Mason eruptive rocks similar to those last mentioned again appear.

Section of Strata on Rio San Saba, Sept. 16, 1856.

1. Cretaceous Limestone. 2. Marly Clay and Sandstone. 3. Upper Carboniferous Limestone.

For the first ten miles after leaving camp the soil was remarkably fertile and the surface hilly and intersected by numerous ravines. Afterwards the country was rocky and barren.

Sept. 18.—After traveling five miles over igneous rocks of the same character as those observed yesterday, we again came to thick layers of coarse quartzose sandstone and conglomerate. The sandstone is hard, highly ferruginous, and often passes into silicious iron ore. At its junction with the eruptive rocks the layers are highly folded and metamorphosed, but a few hundred yards distant present an irregular dip to the east of about 40 degrees. Two miles farther these rocks are again succeeded by granite and other eruptive rocks, which are in places traversed by thick veins of quartz. The granite is mostly soft, coarse grained, and of light gray and red colors. The quartz is compact and milky, and the different veins are sometimes over fifty feet in thickness. Six miles beyond this the sandstone and conglomerate reappear, and thence constitute the prevailing surface formation for the distance of about three miles, after which they disappear and are no more met with during the remainder of the distance to our evening camp, being succeeded by eruptive rocks of the same character as before.

During the day we crossed the Llano River, a small stream of clear water flowing over a bed composed of eruptive rocks. The surface of the country is rough and hilly, and supports a scattered growth of stunted oak.

Distance, 22¼ miles.

Sept. 19.—Shortly after leaving camp we again came to compact and soft Cretaceous Limestone, which continued to be largely developed until we arrived at Fredericksburg. The surface of the country is generally rough and broken, and marked by ridges and conical hills of limestone; soil fertile and in places covered with heavy vegetation. At Fredericksburg the underlaying marly clay is well exposed. Beyond this point, however, it disappears, and is not again met with until we approach San Antonio de Bexar.

From Fredericksburg to San Antonio de Bexar our road was over continuous beds of hard and soft Cretaceous Limestone, which at some points attains a thickness estimated approximately at about eleven hundred feet. It, however, does not differ lithologically or paleontologically from that last described. The surface of the country is generally broken, possesses a rich soil, and affords every inducement to the agriculturalist.

APPENDIX.

GRAYSON COUNTY.

BY GEO. G. SHUMARD.

The county of Grayson was created by the Legislature of Texas in the year 1846, and was fully organized in the same year by the election of its different county officers.

It is situated near the center of the extreme northern tier of counties, and is bounded on the north by Red River, which separates it from the Indian Territory, on the east by Fannin, on the south by Collin and Denton, and on the west by Cooke counties. Its superficial area is a little over nine hundred square miles, and it contains at this time a white population of eight thousand five hundred and eighteen inhabitants, and a voting population of one thousand and twenty-five persons.

Its surface is undulating, and in places somewhat hilly, and is marked by four elevated ridges which traverse the county in different directions.

The first and most elevated of these ridges extends from east to west across the southern portion of the county, and here forms a portion of the main divide between the waters flowing north into Red River and those flowing south into the Gulf of Mexico. Its summit is in some places much more elevated than in others, is usually flat or gently undulating, and varies in width from a few yards to several miles. This ridge enters the county in its southeastern portion, and here forms the elevated district upon which Pilot Grove and Kentucky Town are located. From these points it pursues a westerly course until it approaches a point about midway between the eastern and western boundary lines of the county; thence it turns northwest to form the divide between the headwaters of Choctaw Bayou and Range Creek, beyond which its general course to the western boundary line of the county is a little north of west. The sides of this ridge are usually gently sloping. In some places they are, however, marked by deep rocky ravines, and in others are hilly and much broken.

A second ridge traverses the county in a north and south direction, and forms the divide between the waters of Big Mineral and Choctaw Bayous in the northern and central portions of the county, and several of the head branches of the Trinity River towards the south. Near the center of the county this ridge unites with the one last described, but a few miles farther south is again seen pursuing a separate course. The sides of this ridge are usually smooth and gently sloping. In a few places they are abrupt, and marked by triangular rocky ravines.

A third ridge runs pretty nearly east and west through the southwestern portion of the county, while a fourth, known as Iron Ore or Pilot Knob Ridge, pursues very nearly the same general direction in the northeastern portions of the county. The former is less elevated than either of the others, and forms the divide between Isle du Bois and Bush Creek.

The latter, or Iron Ore Ridge, is much more elevated, presents abruptly sloping sides, and is marked along the summit by a number of conoidal elevations.

The surface of the county mostly consist of smooth undulating prairie, here and there diversified with groves of trees. The slopes are usually gentle, and with the exception of the northeastern and southern portions, which are somewhat hilly and marked by deep ravines, the surface is but little broken.

Grayson county is watered by Red River, which flows along its northern border, and by numerous creeks, many of which contain a constant supply of water, while many others go dry during the summer seasons. Of these creeks those most deserving of note are the Choctaw, Big Mineral, Post Oak, Little Mineral, Shawnee, Iron Ore, Mill, Isle du Bois, Bush, Little Elm, East Fork, White, Lester Grove, and Pilot Grove Creeks. The largest and most important of these creeks empty into Red River, and their beds are usually flat, sandy, and sunk deep below the general level of the country, while their banks are usually either abruptly sloping or vertical. The central and northern portions of the county are drained by the different streams flowing north into Red River, the two largest of which are the Choctaw and Big Mineral Bayous, the first flowing through the northeastern and the second through the northwestern portions of the county, while all the waters south of the dividing ridge running east and west flow into the head branches of the Trinity River. It is worthy of note that with the exception of a few of the western branches of the Big Mineral Bayou, all the creeks flowing in Grayson county have their origin within the limits of the county, and most of them rise near its center.

Good timber, suitable for fuel and building purposes, is very abundant in the northern and western portions of the county, as well as along all the different streams, which are usually densely clothed with trees Small groves of trees are also occasionally seen dotting the uplands of the central and southern portions of the county. The principal varieties of trees occurring upon the uplands are post and blackjack oaks, interspersed occasionally with hickory, black walnut, and more rarely mezquite trees—the last mentioned variety being only seen in the western and southwestern portions of the county. Along the river and creek bottoms the principal growths are Overcup, Spotted, Pin, Black, Red, Chincapin, Post, and Live Oaks; Cottonwood, Hackberry, Pecan, Box Elder, Black Walnut, Sycamore, Bois d'Arc, smooth and rough bark Hickory, Persimmon; White, Black, and Prickly Ash; two varieties of Dogwood; Wild China, Chickasaw Plum, Mulberry, Red and Black Haw, Honey and Black Locust, Swamp Willow, Sassafras, Black and Green Brier, Red Bud, Red Cedar, Gum, Spicewood, Pawpaw, and Wild Cherry trees.

Grayson county is settled by an industrious, moral, and thriving community.* The principal articles of produce of the county are maize, or

* According to the statistical returns for 1859 there are in successful operation in the county, four high schools, two of which are located within the town of Sherman, one in Kentucky Town, and one in Pilot Grove, and forty-two common schools, which are located in various portions of the county. There are also eighteen churches in the county, viz: Six Presbyterian, one Protestant Methodist, six Methodist Episcopal South, one Primitive Baptist, and three Missionary Baptist churches. The county contains eight towns. Sherman, the county seat, is a pleasant, flourishing town, situated near the centre of the county, on the east side of Post Oak Creek, on the northern portion of the Saul Blagg and southern portion of the J. B. McAnair headright surveys. The town was located in 1848, and incorporated by the Legislature in January, 1849. It occupies an area of one square mile, and contains an industrious, thriving population of 613 inhabitants. It contains a good brick

Indian Corn, wheat, and oats. Considerable attention is also there paid to the raising of stock.†

Scientific Geology.

The rock formations of Grayson county are all comprehended in the three systems known to geologists as Quaternary, Tertiary, and Cretaceous.

* * * * * * * * * *

QUATERNARY SYSTEM.

Under this head is included all the rock deposits of more recent origin than the Tertiary formation. This system attains in Grayson county a vertical development of over a hundred feet, and is best exhibited along the banks of the different streams, where vertical sections of these deposits are often exposed to the thickness of forty or fifty feet.

The Quaternary deposits of this region consist: 1st, of Alluvium; 2d, Loess; and 3d, Pebbles.

I. ALLUVIUM.

The Alluvium is the most recent of all the Quaternary deposits, and consist of: 1st, Soils; 2d, Sands; 3d, Clays; 4th, Pebbles; 5th, Calcareous Tufa; 6th, Bog Iron Ore.

1. *Soils.*—As will hereafter be seen, the soils of the county vary considerably in character. They are usually composed of the debris of more ancient formations, together with decomposed vegetables and animal remains. The rocks of this region being usually soft and therefore easily acted upon by atmospheric influences, the soils, as might be expected. are correspondingly thick. For a full description of these soils the reader is referred to the article upon the economical geology of Grayson county.

2. *Sand.*—There are several varieties of sand occurring in Grayson county, one of the principal of which belongs to the valley of Red River, and is fully described in the report upon that stream. (*See Geology of Red River.*) The others are very abundant in the northwestern and northeastern portions of the county, as well as in the beds and along the banks of most of the principal streams. They usually consist of very fine particles, which are in some localities composed almost entirely of pure silex, and in others of silex more or less intermixed with calcareous matter. Their color varies from light gray to brown and yellow. In some places they are largely intermixed with small rounded black ferruginous pebbles, and also often contain numerous fish teeth. These sands are mainly derived from the disintegration of the soft sandstones of the Tertiary and Lower Cretaceous Systems. The pebbles and fish teeth are derived from the conglomerate and sandstone of the Lower Cretaceous Group.

These sands often accumulate to the depth of eight or ten feet in the beds

court house, two churches, two schools, two hotels, two large livery stables, and seven stores, with an aggregate capital invested of near two hundred thousand dollars. Kentucky Town, Pilot Grove, McComb, Whitesboro, and Farmington are all thriving villages located in the county. Preston, on Red River, was at one time a town of considerable importance, but is not now in a flourishing condition. There are at present one saw mill and fifteen flouring or grist mills in the county, of which four are worked by steam, three by water, and nine by oxen.

† The number of cattle in the county in 1859 was 29,192, and of horses 3667.

of the different streams, while in the northeastern and northwestern portions of the county their thickness has been estimated at from twenty to thirty feet.

In the vicinity of Walnut Creek, in the northwestern portion of the county, thick beds of coarse green calcareo-silicious sand, containing small scales of black mica, are met with. It is derived from the disintegration of the coarse green sandstone of that vicinity.

3. *Clay.*—Alluvial deposits of calcareo-argillaceous clay are of frequent occurrence along the different streams in the county. They are usually highly indurated and compact, and vary in color; that occurring along Red River being usually deep red, while those in the interior of the county present various shades of blue, brown, and yellow. These clays are mainly derived from the disintegration of the argillaceous beds of the Lower Cretaceous formation. They sometimes contain a notable quantity of gypsum, and if found in sufficient quantity would constitute valuable fertilizers.

4. *Pebbles* of hard gray limestone and yellow sandstone occur abundantly in the beds of most of the streams in the county. They are usually small and rounded, and are all derived from the destruction of the limestone and sandstone of the Cretaceous System, whose characteristic fossils they often contain. In the beds of Post Oak and Choctaw Creeks thick accumulations of Ostrea, derived from the neighboring strata, are often met with. In many places the surfaces of the prairies are strewn with small rounded pebbles of quartz, jasper, and other silicious rocks. From their appearance these have evidently been transported from a distance, as no rocks of the same character are found in situ in the county.

5 and 6. *Calcareous Tufa and Bog Iron Ore.* — In a few localities deposits of these characters have been discovered in the county, but they do not occur in sufficient abundance to merit a separate consideration.

The deposits thus far described constitute the principal alluvial formations of Grayson county. They are all derived from the destruction of the older rocks, caused by the separate or united action of water, air, and frost, and are still in process of formation from the same causes.

II. LOESS.

The Loess formation, whose existence in Texas was first published by myself in 1852 (see Marcy's Report), is largely developed in Grayson county. It is usually exposed in the form of vertical bluffs along the different streams, and here attains a general thickness of forty or fifty feet. The best exposures of this formation in the county are met with along the banks of Red River, and Post Oak, Choctaw, and Big Mineral Creeks, where good vertical sections of it thirty or forty feet in thickness are frequently exhibited. Wherever examined it has been found reposing upon beds of pebbles, and the line of division between the two is by no means distinct, the one formation gradually running into the other.

This formation is here composed of highly indurated compact silicious and calcareo-silicious clay. That exposed along Red River is made up of alternating bands of marly clay and fine silicious sand, and is usually deeply colored with red oxide of iron, while that occurring in the interior of the county is usually much less ferruginous, of a light yellow color, and homogeneous in character. Not unfrequently it contains small rounded pebbles of white carbonate of lime and silicious rocks, and is sometimes, especially towards its upper portion, thickly marked with decayed roots of vegetables.

This formation is rich in organic remains, consisting mainly of terrestrial and fluviatile shells. These shells are quite numerous, are generally in a good state of preservation, and are equally distributed through every portion of the formation. Fragments of fossil wood and decayed bones are also sometimes met with in this formation.

III. PEBBLES.

As already remarked, the Loess is usually found resting upon beds of pebbles. These occupy the same geological position as those composing the drift in other States, but differ from them in general composition. They are evidently mainly derived from the destruction of Cretaceous strata, are usually quite small and well rounded, and consist of hard light gray limestone and silicious rocks. The silicious pebbles are mostly confined to the sections exposed along the valley of Red River, while those exhibited in the interior of the county are usually composed of calcareous rocks. In the latter fossils of the Upper Cretaceous system are abundantly exhibited. They are also occasionally intermixed with fragments of fossil dicotyledonous wood. These pebble beds vary in thickness from one to five feet, though usually they do not exceed in this respect two feet. Many of them have evidently been transported from a distance, and their deposition must date anterior to the formation of the loess beds. In a few localities they are observed loosely cemented with calcareous and ferruginous paste.

Many of the pebbles already described under the head of alluvium as occurring upon the surfaces of the prairies probably belong to this period, as beds of the same character of rocks are met with several feet in thickness beneath the loess west of Grayson county.

TERTIARY SYSTEM.

The Tertiary System is well developed in Grayson county. It is limited, however, to the north, no rocks of this class being found in its central or southern portions. Towards the northeast these rocks are well exposed, and there form the elevated ridge known as Iron Ore or Pilot Knob Ridge. In this situation they present an average width of four or five miles, and a general thickness of over two hundred feet. A little east of this they are seen extending much farther south. Immediately west of Iron Ore Ridge these rocks disappear entirely, giving place to strata of Lower Cretaceous age, but again make their appearance near the head of Little Mineral Creek, and thence continue uninterruptedly as far as the western boundary of the county. Towards the northwest they constitute almost the entire area watered by the western branches of Big Mineral Bayou.

In Iron Ore Ridge sections of these strata are exposed to the thickness of one hundred and fifty feet, and their general thickness in the county can not fall far short of two hundred and fifty feet.

These rocks, according to their different lithological as well as paleontological characters, are here divided into three distinct groups, which we shall name, 1st, Upper Arenaceous Group; 2d, Middle or Green Sandstone Group; and 3d, Gypseous Clay Group.

I. UPPER OR FERRUGINOUS GROUP.

The strata composing this division are about one hundred and thirty feet in thickness, and occupy the superior position. They vary considerably in

character, being in some places quite hard and firm, and in others quite soft, or but little more than loosely coherent sand. They usually occur in massive beds, and the divisional lines between them are generally very indistinct and often not at all visible. These strata are subdivided according to their lithological character into two distinct groups, which we shall call upper and lower ferruginous groups.

1. *Upper Ferruginous Group.*—The rocks of this division occupy the summit of the formation, and are abundantly encountered along the more elevated portions of Iron Ore Ridge, and also upon the summits of many of the Tertiary hills in the northwestern portions of the county. Their average thickness is estimated at about fifty feet. They consist of hard, yellow, red blue, and ferruginous brown calcareo-silicious sandstone—the percentage of carbonate of lime being usually very large. The rock is usually very compact, and the quartzose grains are scarcely distinguishable in it. It breaks with an uneven fracture, and its freshly fractured surfaces are usually of a light blue color and exhibit a glistening luster, but turn dull earthy and ferruginous colored upon exposure. This rock is highly ferruginous and frequently passes into silicious iron ore. It occurs in massive beds, and the plains of stratification are usually very indistinct. Owing to the large percentage of iron it contains, this rock, whenever exposed, is found to be undergoing rapid disintegration, and is often from the same cause filled with irregular cavities, some of them a foot or more in diameter.

2. *Lower Ferruginous Group.*—These rocks occupy a position immediately below the last, and are exhibited wherever the Tertiary strata are seen in Grayson county. Their average thickness is about seventy-five feet. Good vertical sections of these rocks are frequently exposed along Iron Ore Creek and throughout the entire northwestern portions of the county. They consist of sandstone, which is generally quite soft, being often nothing more than loosely coherent sand. Its usual color is light yellow, from which it passes into shades of red, brown, and gray. It is often highly ferruginous and not unfrequently passes into impure silicious iron ore. The quartzose grains are usually very distinctly exhibited and very fine. This rock generally occurs in heavy massive beds, but in some instances it is found thin bedded, and is sometimes marked by thin bands of hard blue calcareo-silicious sandstone, and at others, especially towards the base, with thin seams of indurated blue, red, and yellow argillaceous clay. In a few instances the beds have been found to contain scattered small silicious pebbles. This rock is in places highly fossiliferous. The fossils are usually limited to two distinct bands, one occurring near the summit and the other towards the base of the formation. These bands vary in thickness from one to three feet, and are usually composed almost entirely of Ostrea firmly cemented into a breccia with calcareous and silicious matter. The teeth and vertebra of fish are also occasionally found in these rocks.

The following section, taken from the bank of Iron Ore Creek at a point where the creek cuts through a portion of Iron Ore Ridge, will exhibit the character and position of these rocks:

SEC. 128.

1. Hard blue and yellow fine-grained glistening calcareo-silicious sandstone, when freshly fractured blue, but turning yellow upon exposure. 30 feet.
2. Soft, rapidly crumbling, fine-grained yellow silicious sandstone. 10 feet.

3. Fossiliferous band composed of ostrea cemented with calcareo-silicious matter. 3 feet.
4. Soft, fine-grained, yellow, rapidly crumbling sandstone, with fossils near the base. 15 feet.
5. Indurated blue and yellow clay with selenite. 5 feet.
6. Lignite. 3 feet.
7. Indurated blue clay with selenite and lignite in small particles. 5 feet.
8. Soft yellow clay with fossils. 5 feet.

II. MIDDLE OR GREEN SANDSTONE GROUP.

Occupying a position immediately below the group last considered we have a series of deposits differing from them both in lithological and paleontological characters. These rocks are limited to the northwestern portion of the county, where sections of them are exposed below the yellow sandstone of the preceding group near fifty feet in thickness. The best sections of these strata are exhibited along Walnut and Cedar Creeks, these streams having cut through the formation to the depth of forty or fifty feet.

The principal rocks of this group consist of sandstone and clay. The sandstone varies somewhat in character, being both soft and hard, and massive and thin bedded, or even schistose. Its color is usually deep green, from which it passes into various shades of red, yellow, and brown. It is composed of coarse quartzose grains cemented by silicious and calcareous matter. In some instances the percentage of lime is very large, in which case the quartzose grains are usually distinct and imbedded in it. In some places it is highly micaceous, the mica existing in the form of small scales of black and yellow colors. Near the summit of the formation the rock is usually much harder than towards the base, the lower beds being usually quite soft and often but little more than loosely coherent sand.

This sandstone is everywhere thickly marked with concretionary masses, which vary in size from a few inches to several feet, and are usually of a spheroidal form. They are the same in composition, but always much harder than the surrounding rock. They are distributed promiscuously through the layers, and are sometimes composed of concentric layers, but more generally they are homogeneous in structure and never exhibit any traces of the plains of stratification marking the surrounding rocks. The rock also in places contains numerous flattened nodules from one to three inches in diameter, of hard, compact, earthy, blue and green argillaceous limestone.

The clay occurs interstratified with the sandstone in layers of from one to three inches in thickness, and also in small irregular masses disseminated through the sandstone. It is usually argillaceous, compact, and indurated, and varies in color from green to blue, yellow, and red. In some localities it is highly arenaceous.

These rocks are sometimes rich in organic remains. The fossils are limited, however, to a few species, and consist mostly of ostrea.

Fossil wood is unusually abundant in this formation. It usually occurs in the form of distinct logs, which are imbedded in the sandstone, and consist of sections of the trunks of exogenous trees. These are very numerous. In one locality no less than eight of them were counted. They vary in diameter from one to three feet, and are often ten or fifteen feet in length. They are usually found occupying a horizontal position, and their general appearance would seem to indicate that they had been drifted to their present position previous to their mineralization. The ligneous structure of the

wood is most perfectly preserved, and the medullary rays and fibrous tissue are very distinct. The mineralizing substance is carbonate of lime. This fossil wood is usually quite soft, of light gray, brown, and yellow colors, and at a little distance can hardly be distinguished from partially decayed logs. Like recent wood, it splits very readily in the direction of the grain, and can be easily separated into distinct fibres.

III. GYPSEOUS CLAY GROUP.

This division occupies the base of the Tertiary System of Grayson county, and consists of gypseous clay, sandstone, lignite, and limestone. Its general thickness is about seventy-five feet, and good sections of it are met with along Iron Ore Creek in the northeastern portion of the county, and also along most of the principal western branches of Big Mineral Bayou.

The clay composes by far the greater portion of this division. It is usually argillaceous, and of a deep blue color. In some places it is largely intermixed with fine silicious sand. Its color also often changes to red, yellow, purple, green, gray, and brown. In some instances all these different colors are exhibited in the same section, giving to the rock a variegated or ribboned-like appearance. This clay is usually highly indurated and exhibits a schistose character. It is generally largely intermixed with selenite, which is disseminated through it in the form of minute lenticular crystals. Sometimes these are so numerous as to constitute a fourth or fifth of its bulk, and the water flowing through this formation is consequently generally bitter and disagreeable to the taste. In a few instances thin seams of selenite have been detected traversing the clay horizontally, and in others the clay appears reticulated with the selenite. Small septaria, composed of hard compact blue argillaceous limestone, are also sometimes met with in the clay.

The limestone occurs mostly in the form of flattened nodules imbedded in the clay. These are generally from one to two inches thick, and vary in width from a few inches to one or two feet. They are usually hard, compact, and of an earthy texture. They are of an iron rust color externally, but when broken exhibit various shades of blue and brown. These nodules usually occur in the clay in the form of distinct bands or layers which are nearly horizontal. Sometimes several of these bands are witnessed in the same section.

The sandstone and lignite occur interstratified with the clay. The former, or sandstone, exists in seams from a fourth of an inch to six or eight feet in thickness, the thicker beds being usually divided by very thin partings of clay. This rock varies in color from light yellow to gray, brown, red, and black, its most usual color being yellow. It is composed of fine quartzose grains loosely cemented with silicious and ferruginous matter. The rock is thin bedded, and the thinner seams are usually pleated. In some instances its texture is hard and firm, but more generally the rock is soft and rapidly crumbling.

The lignite occurs distributed through the clay and sandstone in small irregular masses, and also in distinct seams which are interstratified with the clay. These seams vary in thickness from one to four feet, their usual thickness being about three feet, and are generally nearly horizontal. In some localities sections are exposed exhibiting two seams, one above the other, the spaces between them being occupied with sandstone and clay. In nearly all the sections examined the lignite has been found, both above and below, in direct contact with the clay. The lignite is either of a dark

brown or black color, and is sometimes compact and homogeneous in composition, and at others exhibits distinctly the ligneous fibres of the original wood. In some places it is largely intermixed with selenite in the form of small lenticular crystals.

The rocks of this group are sometimes found to be rich in organic remains. The fossils usually occur in the limestone nodules. Fragments of fossil bones have also been found in one of the lignite beds.

ECONOMICAL GEOLOGY.

SOILS.

As might be anticipated from the varied character of the formations just described, the soils of Grayson county differ greatly in character and productiveness. For convenience of description we will arrange them under the heads of the different formations to which they belong, and will accordingly describe them as, 1st, Alluvial; 2d, Tertiary; 3d, Upper Cretaceous; and 4th, Lower Cretaceous. By adopting this plan the reader will have no difficulty in determining the area occupied by each class of soils by glancing over the county maps accompanying this report.

1. *Alluvial Soil.*—The alluvial soil of the portion of the county bordering on Red River has already been fully treated of in the agricultural portion of the report upon Red River Valley, and its description need not be repeated here. We will merely remark that for productiveness and ease of cultivation it justly ranks among the very best soils in the State.

The creek bottoms in the interior of the county are usually thickly clothed with alluvial soil. This soil is generally productive, and in all respects well adapted for cultivation. It varies somewhat in composition, being in some places highly argillaceous, and in others more or less mixed with calcareous and arenaceous matter. It is usually of a dark color, loose and porous, and well adapted for the retention of heat and moisture. It is generally clothed with luxuriant vegetation, consisting of trees, vines, and dense undergrowth. Among the trees the most abundant species are Overcup, Spotted, Pin, Black, Red, and Chincapin Oaks; Hackberry, Pecan, Box-elder, Black Walnut, Sycamore; White, Black, and Prickly Ash; Dogwood, Chickasaw Plum, Red and Black Haw, Honey and Black Locust, Swamp Willow, Bois d'Arc, Sassafras, Black and Green Brier, Redbud, Red Cedar, Gum, Spicewood, and occasionally Pawpaw.

Vines are unusually abundant in these regions. They consist principally of the grape, of which there are several varieties, and the poison oak (*Rhus toxicodendron*), while the undergrowth is of such a character as usually accompany rich alluvial soils.

These soils are well adapted to the cultivation of corn, wheat, oats, as well as that of almost every other article of produce suited to the climate.

Tertiary Soils.—The soils overlying the rocks of the Tertiary System are usually less productive than the preceding varieties. Some of them are, however, very favorably constituted, and afford abundant crops of corn, wheat, and oats. These soils are mainly derived from the decomposition of the rocks of the Tertiary strata, and consequently vary in character, being in some places highly arenaceous, in others argillaceous, and in others more or less mixed.

The first variety, or arenaceous soil, is not very productive, and but poorly adapted for cultivation. It is well exhibited along Iron Ore Ridge,

as well as at some points in the extreme northern portion of the county. It usually consists of fine yellow silicious sand, with occasionally more or less admixture of carbonate of lime and iron. This soil generally supports a good growth of Blackjack and Post Oak trees, which are usually accompanied by but little undergrowth.

The argillaceous or clay soil is much less abundantly distributed than the preceding variety, being limited to a few small localities only. It usually contains in its composition a large percentage of gypsum, and being generally compact and impervious to water is of but little value for agricultural purposes. It is usually covered with short grass, and trees are but seldom observed upon it.

The third variety or mixed soil is composed of sand and clay in various proportions, with often a large admixture of carbonate of lime, gypsum, and iron. It is often of a dark or nearly black color when freshly plowed, but turns yellow upon exposure. This soil absorbs heat readily, is usually retentive of moisture, and is therefore well adapted to the cultivation of the different staples usually cultivated in this region of country. It is abundantly seen in the northeastern portion of the county, and is the prevailing soil throughout the entire region watered by the western branches of Big Mineral Bayou. It is often densely clothed with trees, the two principal varieties of which are Post and Blackjack Oaks.

Cretaceous Soils.—Like those of the Tertiary system, the soils of the Cretaceous period vary considerably in character. Those overlying the rocks of the upper division of this group are usually very favorably constituted and highly productive, yielding in abundance almost every article of produce adapted to the climate. Of these soils there are two principal varieties. The first is confined to the region immediately north of Iron Ore Ridge. This soil is usually porous and absorbs heat and moisture readily. Its color varies from dark brown to red and black. It is composed of lime, sand, and clay in various proportions, and generally possesses a highly retentive sub-soil. It supports in places a good growth of Post and Blackjack Oak trees. The second, or "black-waxy soil," is too well known throughout the State to require a description in this place. With a few local exceptions it occupies the entire region south of Iron Ore Ridge, colored on the county map as Upper Cretaceous. It is usually of the most productive character, yielding in abundance wheat, corn, oats, and rye. This soil appears unfavorable, however, to the growth of trees, and the region occupied by it usually consists of undulating prairie or prairie thickets.

Lower Cretaceous Soil.—There are four varieties of soils in the county derived from the decomposition of the Lower Cretaceous strata.

The first of these is mainly derived from the yellow sandstone, and consists of fine yellow silicious sand, with an admixture of clay, lime, and iron. It is both porous and retentive of moisture and is moderately fertile.

The second variety, or mixed soil, occurs near the junction of the sandstone and marly clay. It contains in its composition clay, sand, gypsum, and carbonate of lime in variable proportions. From its constituents this soil has all the elements of fertility, but owing to the general predominance of clay over the other ingredients is but poorly adapted to withstand drought, and on that account is not productive.

The third variety is derived principally from the marly clay or septaria beds, and is composed of argillaceous clay, more or less mixed with gypsum and carbonate of lime—there usually being a deficiency of sand. Its color varies from blue to gray, yellow, and chocolate. This soil, which, along with the preceding variety, is known in the county as chocolate soil, is

sometimes productive, but much more generally it is too compact, which causes it to stand the drought but poorly and renders it of but little value for agricultural purposes. This soil is abundantly met with in the region watered by most of the eastern branches of Big Mineral Bayou. It is usually covered with short grass.

The fourth variety, or *Cactus soil*, differs from the preceding variety in being composed almost entirely of tenacious argillaceous clay of nearly white, light gray, or blue colors. It is very compact, being altogether impervious to water and bakes hard in the sun. With the exception of an occasional stunted growth of cactus, or common prickly pear, it is usually devoid of vegetation. This soil is quite limited in its extent, being confined to small isolated areas, and may be considered as totally worthless for agricultural purposes.

These compose the principal varieties of soil in Grayson county. Other varieties are occasionally met with, but they occupy a very limited area, and are, therefore, unimportant. Most of these soils are very favorably constituted and are capable of abundantly producing every article of produce adapted to the climate, while a few of them are found deficient in one or more of the elements necessary for good soils. These deficiencies, however, can usually be very readily supplied by a judicious admixture of other soils occurring in the vicinity.

AGRICULTURE.

Among the different articles of produce cultivated in the county the most important are Indian corn or maize, wheat, oats, and cotton.

Indian Corn.—This valuable grain is extensively cultivated in every portion of the county.* Some of its soils, however, are found much better adapted for its growth than others, and the average yield, therefore, varies in different portions of the county from ten to forty bushels per acre. In Red River Valley as well as upon many of the creek bottoms in the interior of the county the average yield per acre is not less than forty bushels, while along the summit of Iron Ore Ridge in the northwestern portion of the county it often falls as low as ten bushels per acre. The average annual crop throughout the county may be safely estimated at about twenty-seven bushels to each acre cultivated. It may here be proper to state that this estimate is made not for a single year, but for a period of seven or eight years. During favorable seasons crops of fifty or sixty bushels of corn to the acre cultivated are by no means uncommon in the alluvial as well as in some of the better classes of upland soils in the county.

There are many different kinds of seed made use of in the county. The most usual varieties planted, however, are the gourd-seed and white and yellow flint. Sometimes these are kept distinct, but much more frequently they are suffered to become mixed, so that no one particular variety can be distinguished. The most favorable season for planting is in the latter part of March or the beginning of April, and for gathering about the latter part of September or the beginning of October. In preparing the ground for the reception of the seed preference is almost always given to deep plowing, as by this means the corn is enabled the more effectually to withstand the season of drought and is not so liable to be affected by the spring frosts.

* According to the statistical returns for the year 1858 the number of acres of land in cultivation in corn in Grayson county during that year was 12,359. The amount of corn produced in the county during that year would, therefore, according to the above estimate, amount to nearly three hundred and thirty-four thousand bushels.

The corn crops of this region are but little affected by the weevil or by disease of any character. They are sometimes, however, severly injured by drought, which has in several instances caused a partial or entire failure of the crop.

Wheat.—This cereal is extensively cultivated in almost every portion of the county, and as an article of produce ranks second in importance only to that of corn. Like the latter, the amount produced in different portions of the county varies according to the different character of soil; in some regions twenty-five or even thirty bushels to the acre cultivated being by no means an uncommon crop, while in others the annual amount produced per acre rarely exceeds ten or eleven bushels. The soils of the county best adapted for its cultivation appear to be those overlying the upper division of the Cretaceous System and the Red River and creek bottom alluviums. Fair average crops are also produced from some of the soils overlying the arenaceous beds of the Tertiary and lower division of the Cretaceous Systems, but as a general rule these latter are much better adapted for the growth of corn and cotton than for wheat.

The annual average crop upon all the soils throughout the county may be estimated at about eighteen bushels of wheat to each acre in cultivation. According to the statistical returns for the year 1858 the number of acres cultivated in wheat in the county was seven thousand two hundred and forty-three. The amount of wheat produced in the county during that year would, therefore, according to the above estimate, be over one hundred and thirty thousand bushels.

In preparing the ground for the reception of the seed preference is given by many to deep plowing; others, however, appear to prefer light plowing, and for various reasons think it best. The usual time for planting is from the first of September to the first of October, and for gathering, about the first of June. The wheat crops of this region are sometimes seriously injured by drought and late frosts, but are generally little liable to the diseases that sometimes so seriously affect the wheat crops in other portions of the United States. They are here sometimes slightly affected with the rust and smut, but these diseases seldom do much damage. The weevil are also sometimes a little troublesome to the wheat when in the stack, but seldom do any damage after the wheat is threshed out.

Oats.—Oats grow well in almost every portion of the county, but like the former articles, are often injured by drought. They are also sometimes seriously affected with the rust. In the year 1858 the entire crop of oats in the county was destroyed from this cause. The average annual crop throughout the county is estimated at about thirty-eight bushels to each acre in cultivation. On the better varieties of soils forty-five or fifty bushels to the acre would seem to be an average crop, and during favorable seasons we sometimes hear of crops of seventy or seventy-five bushels to the acre, while crops averaging sixty bushels per acre are by no means uncommon upon some of the better varieties of soils in the county.

The usual time for planting oats is in the latter portion of February and the beginning of March, and for gathering, about the twentieth or twenty-fifth of June.

Cotton.—Owing to its remote situation from market but little attention has heretofore been devoted in this county to the cultivation of the great staple—cotton. The result, however, of the few experiments that have been made are sufficient to induce the belief that this may hereafter become a profitable cotton growing district. Many of the soils of the county are very favorably constituted for the growth of cotton, and a number of its

planters are beginning to turn their attention towards its cultivation. Its average yield, as far as tried in the alluvial portion of the county bordering on Red River, is from four hundred and fifty to five hundred pounds of lint cotton to the acre. Upon the uplands the soils best adapted for its growth appear to be the Tertiary and Lower Cretaceous sandy soils, upon which crops as high as four hundred pounds of lint cotton to the acre have been produced. The calcareous soils overlying the rocks of the upper division of the Cretaceous System do not appear to be so well adapted for the growth of this article, the plants upon these soils dying out before they arrive at maturity. The kind of seed preferred in this region is a variety of the Mexican known as the *Petty Gulf*.

Chinese Sugar Corn. — This article grows most luxuriantly in every portion of the county. It but seldom requires much care in its cultivation, receiving generally but little attention after being planted, and besides its valuable saccharine qualities, yields an abundance of excellent fodder.

Rye.—Some attention has been paid in the county to the cultivation of this article. It usually grows well, and the crops but seldom fail.

Barley. — Most of the soils of the county are well adapted to the cultivation of this article. But for want of a market but little of it is at present cultivated. Wherever tried in the county it has been found to grow well.

Tobacco.—This article has been successfully cultivated in various portions of the county. The plant here grows most luxuriantly and speedily attains a large size, but the leaves are usually thinner and lighter than those of Virginia and Kentucky. The tobacco is of excellent flavor, and would command a good price in the market.

Garden Vegetables,—such as potatoes, onions, cabbage, beets, turnips, parsnips, melons, peas, beans, as well as almost every other article adapted to the climate,—grow well in the county.

Fruit.—Some varieties of fruit, such as peaches, plums, and grapes, appear to grow well upon many of the soils of the county. Apples and pears, however, do not appear to grow well. Many attempts have been made to cultivate these two articles in this region, but with a few exceptions they have proved unsuccessful. Wild grapes and plums are very abundant upon many of the alluvial soils of the county. The principal variety of the latter is a small sweet plum known as the Chickasaw plum, while the former present several varieties, among which the Post Oak, Mustang, and common Winter Grape are the most abundant species. They are usually confined to the river or creek bottoms. In the former situation the vines are often so thickly matted together as to render travel in that region exceedingly difficult.

Grasses.—Many efforts have been made in this region to cultivate the more common grasses of the United States, such as clover, timothy, and blue grass; but, while a few of them have succeeded, most of them have proved unsuccessful. Other grasses, however, of more limited cultivation in the United States have been here tried with much more favorable results. Among the most prominent of these may be mentioned the Millet, Hungarian, and Bermuda grasses, all of which have been found to grow luxuriantly in almost every portion of the county. They usually require but little care in their cultivation, and are found to answer all the purposes of the other varieties of grass usually cultivated farther north.

Among the indigenous grasses a number of varieties occur, all of which are highly nutritious, and being generally much better adapted to the soil and climate than the foreign varieties, could be here cultivated with but little labor or expense. Among these the most important is the mezquite,

which is found growing luxuriantly in the southwestern as well as in other portions of the county. I am not aware that any effort has been made to cultivate this valuable grass in the county, but it is the universal opinion of its citizens that it could be here cultivated without any difficulty, while in other portions of Texas, as well as in some of the adjoining States, its cultivation has been tried with complete success. This grass is highly nutritious, and horses and cattle usually prefer it to all other varieties.

SPRINGS.

Grayson county possesses numerous springs of water, many of which are permanent, while others go dry during the summer season. The water varies considerably in character. That flowing from the arenaceous beds of the Tertiary and Lower Cretaceous and the limestone of the Upper Cretaceous Systems is usually clear, wholesome, and agreeable to the taste, while that flowing from the gypseous clay of the Tertiary and Lower Cretaceous groups is usually highly impregnated with the salts of iron and other impurities, and is bitter, nauseous to the taste, and unfit for use. The latter variety is limited to the northern and western portions of the county; that found towards the east being usually good and agreeable to the taste. In the northwestern portion of the county several springs occur which are so highly impregnated with sulphate of iron as to produce when drunk rapid emesis and other symptoms indicative of severe gastro-intestinal disorder.

Medicinal Springs.—Several springs with water possessing valuable medicinal qualities occur in the county. One of the most important of these is situated on Sec. 48, No. 15, University land, and flows from sandstone of the Tertiary formation. The water is clear, cool, and agreeable to the taste, is strongly impregnated with iron, and deposits a heavy sediment of brown and yellow oxide of iron upon standing. The spring furnishes an abundant supply of water during the entire year, and it may hereafter become a favorite resort for invalids.

Wells.—Wherever natural springs do not exist in the county water can always be obtained artificially by means of wells, which need seldom or never be very deep, a constant supply of water being usually obtained between the depths of fifteen and fifty feet beneath the surface. In only a few instances has it been found necessary to go beyond the depth of forty feet for this purpose.

MATERIALS FOR CONSTRUCTION.

Grayson county is well supplied with materials for construction. As we have already seen, good building timber is abundant in various portions of the county, while rock materials sufficiently firm and durable for all ordinary purposes occur abundantly in the Tertiary and Upper and Lower Cretaceous Systems of the county.

In the Tertiary System the hard blue and yellow rock described as occurring abundantly in the upper portion of Iron Ore Ridge would furnish a moderately durable building stone. It contains in its composition, however, a large percentage of carbonate of lime, and would, therefore, not answer well as a fire stone. The hard blue and gray limestones of the Upper Cretaceous and the blue glistening calcareo-silicious sandstone of the Lower Cretaceous Systems, would all furnish cheap and durable materials for building. Some of the former are sufficiently hard and compact to receive a good polish.

Brick Clay.—Clay suitable for burning into bricks is abundant in various portions of the county, and bricks manufactured in this region will, for beauty and durability, compare very favorably with any other bricks manufactured in the State.

Lime suitable for burning into quick lime is very abundant in connection with the Cretaceous hills of the county.

Hydraulic Lime. — The septaria of the septaria beds would furnish a good quality of hydraulic cement. From the abundance of these septaria in various portions of the county this valuable material can here be manufactured in very large quantity. Rock suitable for the manufacture of hydraulic cement also occurs abundantly in the upper beds of the Tertiary System in the northeastern portions of the county.

Sand sufficiently sharp for mortar is abundant in the northern portion of the county as well as in the beds of most of the streams.

Gypsum. — This article is abundant in the county. It usually, however, occurs in the form of selenite, disseminated in very fine crystals in the clays of the Tertiary and Lower Cretaceous Systems. In some of these clays it is so abundant as to constitute a fourth or fifth of its bulk, and would afford an excellent fertilizer to the poorer varieties of soil in the county. In some localities the selenite occurs in masses several inches in thickness, and might be collected in sufficient quantity to be profitably manufactured into Plaster of Paris.

Potter's Clay.—Clay suitable for pottery occurs abundantly in connexion with the Tertiary strata along Iron Ore Creek, and in the northwestern portion of the county. The clay of the Lower Cretaceous System usually contains a very large percentage of carbonate of lime, and is therefore unfit for burning into pottery.

Lignite.—Extensive beds of lignite occur in connexion with the Tertiary strata in the northeastern and northwestern portions of the county. It is also found disseminated in small particles through the clays and sandstones of the Lower Cretaceous formation in various other portions of the county. The thickness of the former varies from one to four feet, and sometimes two distinct seams, separated by partings of clay and sandstone, are visible in the same section. The lignite varies considerably in character. In many places the woody structure is still visible in it, while in others it is homogeneous in texture, and exhibits no traces of organization. Its color varies from dark brown to jet black, and it exhibits different degrees of hardness. Generally it is hard, breaking with a smooth fracture, but crumbles readily into a brown powder upon exposure to the atmosphere. In some places it is largely intermixed with iron and selenite, the latter in the form of minute crystals disseminated promiscuously through the mass. Fragments of bones and other fossils have been found in connexion with these beds.

This lignite is as a fuel inferior in quality to the true coal, but may be made to answer many of the purposes for which the latter is used. The few experiments heretofore made with it in the county by blacksmiths have proved unsuccessful. But this may be owing to the trials only having been made with such as has been exposed for a long while to the weather. It burns with a strong penetrating odor and a bright flame.

METALLIC ORES.

Iron.—The ores of iron are abundantly associated with the Tertiary strata of this region. The principal ore is a dark brown hematite, which is usually quite porous and very largely intermixed with silicious matter. In some lo-

calities it is sufficiently pure to admit of being wrought, but much more generally it contains too much silex to admit of being worked with profit.

Red Hematite.—Argillaceous hematite is found in the northwestern portion of the county.

Sulphuret of Iron occurs in small irregular masses, sometimes beautifully crystalized, in the clays and sandstones of the Tertiary and Cretaceous Systems. Owing to its bright metallic lustre it is often mistaken for gold.

Lead.—Small crystals of sulphuret of lead, or galena, have been found in connexion with the Upper Cretaceous strata in several portions of the county. There are, however, no evidence of this material occurring in sufficient abundance in any portion of the county to admit of its being profitably worked.

ROAD MATERIALS.

Most of the pebbles occurring so abundantly in the bed of Post Oak Creek as well as those of many other streams in the county would furnish tolerably good road materials. The hard limestone in the northeastern portion of the county and the blue glistening sandstone of the Tertiary and Lower Cretaceous Systems would also answer for this purpose.

MARLS.

Calcareous Marl, composed of nearly pure finely pulverized carbonate of lime, is found in connexion with the Upper Cretaceous strata in the southeastern portion of the county. It would afford a valuable fertilizer to some of the more arenaceous soils of the county.

A very fair quality of calcareous substance as a fertilizer also exists in the marly clay of the Lower Cretaceous strata.

Silicious Marl.—This valuable fertilizer occurs in the northwestern portion of the county, where it is derived from the disintegration of the green sandstone of the Tertiary strata.

Table of Average Produce on the different Soils in the County.

	Red River Lands.	Creek Bottom.	Upper Tertiary of Iron Ore Ridge.	Lower Tertiary.	Upper Cretaceous Calcareous	Lower Cretaceous Sandy.	Lower Cretaceous Clay mix'd.	Lower Cretaceous Clay.
Corn (bush.)	40	35	10	25	30	30	25	18
Wheat, "	20	20	10	16	20	16	15	10
Oats, "	50	40	....	30	40	35	.....	
Cotton (lbs.)	500	350	.....	300	.....	300	.....	

GEOLOGICAL SURVEY OF TEXAS.

ABSTRACT FROM THE REPORT SUBMITTED TO THE LEGISLATURE AT ITS EIGHTH SESSION, BY B. F. SHUMARD, M. D., STATE GEOLOGIST.

In the commencement of our Geological Survey it was thought advisable to make a reconnoissance of as large a district of the State as possible, in order to form some idea of the general character and boundaries of the formations, previous to our more detailed surveys of counties. These general lines of exploration have now been extended over a considerable portion of Eastern and Middle Texas, and sections have been made as follows:

1st. A section from Austin to Houston, one hundred and seventy-two miles.

2d. From Hempstead to Sour Lake in Hardin county, one hundred and twenty-two miles.

3d. From Sour Lake through Hardin, Tyler, Jasper, Sabine, San Augustine, Nacogdoches, Rusk, Harrison, Cass, to Red River in Bowie, three hundred miles.

4th. From Henderson in Rusk, through Cherokee, Anderson, Freestone, Limestone, to Waco in McLennan, one hundred and eighty miles.

5th. From Austin through Williamson, Bell, McLennan, Bosque, Johnson, Parker, Palo Pinto, to Fort Belknap in Young, two hundred and forty miles.

6th. From Fort Belknap through Buchanan, Eastland, to Camp Colorado in Coleman, one hundred miles.

7th. From Camp Colorado through Brown, Lampasas, Burnet, to Austin, one hundred and fifty miles.

8th. From Austin to San Antonio, thence through Bexar, Atascosa, Live Oak, to Corpus Christi in Nueces, one hundred and eighty miles.

9th. From Corpus Christi through Refugio, Goliad, De Witt, Gonzales, Caldwell, to Austin, one hundred and sixty miles.

10th. From Corsicana in Navarro through Limestone, Falls, to Belton in Bell county, one hundred miles.

In making these preliminary surveys careful sections of the strata have been made at all points of outcrop within reasonable distances of the routes traveled, and the thickness, stratigraphical order, dip, and mineral and fossil characters of the various beds have been determined with as much precision as possible. Frequent barometrical observations were made to ascertain the elevation of the country above tide-water, and much attention has been directed to obtaining a correct knowledge of the topographical features and the kinds and quality of timber of the districts explored.

Besides accomplishing the above, we have made detailed surveys of the counties of Grayson, Red River, Lamar, Bowie, Cass, Fannin, Rusk, Navarro, McLennan, Bosque, Coryell, Calwell, Guadaloupe, Burnet, Washington, and partial surveys of Travis, Bastrop, Fayette, and Young.

It will thus be seen that besides a general survey extending over a vast district, we have made minute and final surveys of fifteen counties, and partially surveyed several others.

During the winter and part of the spring months the several members of the corps were actively engaged in the geological rooms and laboratory,

unpacking, labeling, classifying, and arranging the extensive collections of geological specimens accumulated there, in making analyses of soils, rocks, minerals, ores, coals, etc., and in constructing maps, sections, and diagrams, for illustrating our reports.

The investigations of the Geological Survey have already developed results of the highest interest.* It is now known that within the limits of Texas, occur the most complete series of geological formations to be found in any State in the Union, ranging, as they do, from the Potsdam Sandstone of the Paleozoic era to the latest Tertiary, and presenting an aggregate thickness of many thousand feet. A thorough and systematic study of these different geological groups cannot fail to afford results of the highest scientific and practical value.

Our partial explorations show the existence of an extensive coal formation in the northern part of the State, that will exercise a most important influence on her future welfare and prosperity. We are not now able to define the precise boundaries of the Texas Coal Measures. To do this with precision would require a much more detailed investigation than the limited time at our disposal has permitted us to make. It may, however, be stated as a reasonable estimate, that the area occupied by the coal strata can not fall short of four or five thousand square miles. Taking Fort Belknap as a starting point, we have found this formation to extend uninterruptedly southeastwardly to Patrick's Creek in the S. W. part of Parker county, a distance of more than sixty miles; westwardly about forty miles; and southwardly beyond Camp Colorado in Coleman county, say one hundred miles. We have not traced it in its northward extension more than six or eight miles from Fort Belknap, but it is highly probable that it reaches into Archer, Baylor, and Clay counties. It is also probable that the same formation is developed in San Saba and some of the counties adjacent.

The strata composing the Coal Measures of the region we have described have a thickness estimated at not less than three hundred feet, and consist of quartzose and argillaceous sandstones, limestones, grits, and conglomerates; argillaceous and calcareous shales; fire, potter's, and pipe clays; and coal. Some of these strata, and particularly the limestones and shales, are filled with organic remains, among which we have recognized many species which are highly characteristic of the Coal Measures of Missouri, Kentucky, Illinois, and Iowa. The shales also frequently contain large and beautiful crystals of selenite, and rounded masses of excellent iron ore. The coal at all of the localities examined reposes either on fire-clay or shale.

In Young and Buchanan counties outcrops of coal occur at a number of points, and in the former county it has been struck at many places in excavations for wells. We have here recognized four distinct coal seams, varying from six inches to five feet, and presenting an aggregate thickness of eight or nine feet. At the mouth of Whisky Creek, near Fort Belknap, is an interesting exposure, exhibiting three distinct coal beds, separated by bands of limestone, fire-clay, sandstone, and shale, and the whole surmounted by sandstone and conglomerate.

In regard to the quantity of coal, we do not speak in extravagant terms when we assert that in the region under consideration there is an abundance of this most valuable mineral fuel to supply the present and future

*It is not possible to give here the results of our operations the present season, since the parties are now in the field, and I have not access to their notes and specimens.

demands of the State for centuries. With reference to the quality of the Texas coal, it may be stated that it will compare favorably with most of the coals which are wrought in Missouri, Illinois, and Iowa. In general appearance and weight it resembles very closely the coal of St. Louis, Missouri, and Belleville, Illinois.

The following analysis, made by Dr. Riddell, in the State Laboratory, shows the chemical constitution of an average specimen from a bed three and a half feet thick, exposed on Whisky Creek two miles north of Fort Belknap:

Total matter volatile at red heat	44.136
Weight of coke	55.864
	100.000

Amount of moisture expelled at 212°	7.8689
Additional matter volatile at red heat	36.2671
Fixed carbon (coke)	52.8060
Ash (ochreous brown)	3.0580
	100.0000

According to Dr. Riddell, this coal cokes without changing its form, and burns with a bright yellow flame.

For the sake of comparison we subjoin the following analysis, by Prof. J. D. Whitney, chemist of the Geological Survey of Iowa, showing the composition of a specimen from Van Buren county, Iowa, regarded as one of the best coals in that State:

Moisture	5.30
Volatile and combustible	37.98
Fixed carbon	54.35
Ash	2.37
	100.00

Besides the coal area just described, it is highly probable that productive coal beds will be discovered in the extreme western part of the State, as we have indisputable evidence of the existence of the true coal measures in that region. Should future researches develop the existence of workable seams of coal in this portion of our State, they will prove a fertile source of wealth, and their value can scarcely be overestimated.

Connected with the Tertiary formation, which occupies a vast area in the eastern and middle portions of the State, are extensive beds of brown coal, or lignite, which will, I think, be of great service to the public. Our detailed examinations in Rusk show that a large portion of this county is underlaid by deposits of this material, exposures of which occur at a great many localities. The beds examined vary from six inches to eight feet in thickness and are associated with bituminous shale, fire and potter's clay, soft quartzose, and argillaceous sandstone, impure limestone, and iron ore. At a number of localities visited the lignite appears to be of good quality and adapted for the ordinary purposes of fuel. It varies greatly in character in different sections of the county, some specimens exhibiting the

woody fiber with tolerable distinctness, while others show no traces of organic structure, being dull, shining black, and very compact in texture.*

In the N.E. corner of Cass county, at "Stone Coal Bluff," examined by Dr. G. G. Shumard, is a bed of lignite ten feet thick, which resembles the bituminous coal of Fort Belknap, both in external character and chemical composition, and it is quite probable that it may be employed to advantage in the manufacture of iron. Regular seams of lignite of more or less value have been discovered by different members of the corps, in the counties of Grayson, Harrison, Caldwell, Guadaloupe, Bastrop, Anderson, and Fayette, and we have heard of many other localities in various sections of the State which we have not yet been able to visit.

Brown coal, or lignite, is in general inferior to true bituminous coal, which belongs to an older geological formation, nevertheless its importance has usually been underrated. In Germany and Prussia large quantities of lignite are annually mined to supply the inhabitants with fuel, and the Tertiary brown coal of the Pacific coast has been successfully employed for purposes of ocean steam navigation. It is estimated that the heat given out by lignite is about one-third more than that of wood. The better varieties of Texas lignite may not only be used as fuel, but it is also probable that some of them may also be employed for the manufacture of illuminating gas.

Among the combustible minerals may also be mentioned the occurrence of *Petroleum*, which has been observed at several points in the State. The most important locality visited is at Sour Lake in Hardin county, where this substance may be collected in considerable quantity from the surfaces of the remarkable acid springs adjacent to the lake. The earth for some distance around these springs is also so highly charged with bitumen as to be employed for purposes of illumination and to some extent as a fuel.

In addition to her coal deposits, Texas embraces within her limits vast accumulations of iron ore, which require only judicious expenditures of labor and capital to be converted into fertile sources of wealth.

Until the commencement of the present survey, it was not known that we had workable deposits of iron, except in one or two localities. But our labors have demonstrated the important fact that we have a vast iron region in the eastern part of the State, embracing considerable areas in Cass, Harrison, Rusk, Panola, Smith, San Augustine, and Shelby counties. The ore deposits belong to the Tertiary era, and consist chiefly of hematites and limonites, of which there are several varieties. We have also found in this district extensive beds of carbonate of iron.

According to Dr. G. G. Shumard, Cass county alone is capable of supplying a number of furnaces with an abundance of excellent iron ore for many years. The ore occurs here in regular layers, which sometimes attain a thickness of fifty feet. The only iron furnace our State can boast of is located in this county. It was erected several years since, by Mr. Nash, and has been in nearly constant, and I believe profitable, operation

*An example of this variety, from the neighborhood of Iron Mountain P. O., analyzed by Dr. Riddell, gave the following result:

Specific gravity 1.094.

Moisture expelled at 212°	15.701
Matter volatile at red heat	4.105
Fixed carbon	79.137
Ash	1.057
	100.000

up to the present time. The ore is mined near the furnace, and the kinds preferred are a porous variety of hematite, termed by the proprietors "honey-comb ore," and compact brown hematite. The pig metal and castings produced from these ores are of excellent quality, and command a high price in the market.*

Our detailed examinations in Rusk county have developed the occurrence of almost inexhaustible deposits of workable hematite, similar to that found in Cass,† while our general surveys in Cherokee, Nacogdoches, and the other counties above enumerated, have convinced us that farther explorations will reveal there also the existence of equally extensive accumulations of this important element of State wealth.

Other deposits of iron occur in the Tertiary strata in the Middle Division of the State, but so far as our observations have been carried these ores are inferior to those found in the East. In the counties of Caldwell and Guadaloupe, examined by Dr. Riddell, are heavy deposits of iron ore, but they contain such a large proportion of silex, in the form of sand, as to render them generally unfit for profitable smelting. We have fair workable ores from Bastrop and Llano counties, but further researches are necessary before we can give a positive opinion respecting their value.

Throughout the region of the Coal Measures in the northern part of the State, we frequently find bands of argillaceous iron ore interstratified with the gypseous shales, while the surface of the ground is often thickly strewn with masses of rich iron ore from the size of a filbert to that of the double-fist. In Young and Buchanan counties these ores are often quite abundant in places, and they appear to be well adapted for smelting, although our investigations have not been sufficiently minute to enable us to determine whether they occur in sufficient quantity to be wrought with profit.

Lead.—In the districts examined, no important deposits of lead have yet been found, but we have received from different parts of the State specimens of galena, or sulphuret of lead, which induce the belief that future researches will develop the existence of valuable veins of this metal. Thus we have samples of remarkably rich ore from the western part of the State, near El Paso, the Wichita Mountains, and Fort San Saba. In Llano county occurs an interesting ore, the molybdate of lead, which is quite rare in mineralogical collections.

* Dr. Riddell's analysis of an average specimen of the honey-comb variety from the Nash mines yielded the following result:

Specific gravity, 2.2891.

Moisture and matter volatile at red heat	12.227
Silica	8.122
Per-oxide of iron	79.604
Loss	.047
	100.000

† Dr. Riddell's analysis of a specimen taken from an extensive ore deposit in Rusk county, about four miles east of Sulphur Springs, gave:

Specific gravity, 3.3245.

Alumina	1.0360
Silicious matter insoluble in acids	8.7941
Per-oxide of iron	71.7826
Water	18.3873
	100.0000

The specimen analyzed represents a variety that is very common throughout the iron region of this part of the State.

Copper.—According to Dr. Geo. G. Shumard, small rounded masses of the oxide and carbonate of copper occur distributed abundantly over the surface of the country towards the sources of the Big Wichita, Brazos, and Red rivers, and it is not improbable that productive veins of copper will be found in this region.

We have also remarkably fine specimens of native carbonate and oxide of copper from the extreme western part of the State.

Silver.—All the sulphurets of lead that we have seen from Texas are more or less argentiferous. A specimen analyzed by Dr. Riddell contains nearly nine ounces of silver to the ton of ore.

Gypsum.—This valuable material has a vast development both horizontally and vertically in our State. According to Dr. Geo. G. Shumard,* who has had fine opportunities for exploring the gypsum district in Texas and the adjacent territories, it occurs in the greatest abundance in the country watered by the upper portion of the Canadian, Red, Big and Little Wichita, Brazos, and Pecos Rivers. On Red River the gypsum beds are from a few inches to thirty feet thick. On Delaware Creek, a few miles below its source, they are sixty feet, while between the Big Wichita and Brazos Rivers there are hills nearly seven hundred feet high composed almost entirely of this material. It is usually of pure white, more or less granular, and sometimes resembles loaf-sugar. Occasionally it assumes the character of fibrous gypsum, selenite, and compact alabaster. We have also found gypsum in the form of selenite somewhat abundantly disseminated through the marls of the Cretaceous Period in Grayson county, and those of the Coal Measures in Young and Buchanan. The crystals are frequently quite large, and form beautiful cabinet specimens. The gypsum field of Texas is believed to be the largest in the world, and capable of supplying all the demands of the South and West for thousands of years.

In several counties we have discovered extensive deposits of potter's, pipe, and fire clays, and inexhaustible beds of calcareous marl. Limestones, sandstones, and other materials adapted for building purposes, have also been met with in nearly every portion of the country examined. In Burnet county we have found extensive tracts underlaid by building rocks of great beauty and durability, and there occurs here a beautiful variegated limestone of remarkably fine texture, which receives a good polish, and forms a handsome marble for ornamental work. A considerable district in this county is likewise occupied by a rather coarse red granite, which, if properly selected, may be advantageously employed in the construction of such works as require great strength and durability. In the State of Missouri a rock of the same kind is frequently employed for mill-stones, for which purpose it is tolerably well adapted.

In the counties of Young and Rusk valuable beds of hydraulic limestone occur, and we have collected specimens from other parts of the State which appear to possess hydraulic properties, but farther experiments are necessary before we can decide positively upon their value.

Our collection of soils, clays, rocks, ores, coals, and fossils, is quite extensive, and already embraces many objects of great interest and rarity, and contains many species new to science. The suite of organic remains is especially large and valuable. These, when carefully studied, will throw considerable light on some disputed points in the geology of the West and Southwest.

* Unpublished report on the Geology of the U. S. Expedition, under Capt. J. Pope, for boring artesian wells, etc.

The agricultural department of the survey has received a full share of our attention. The different varieties of soils and subsoils have been carefully collected for chemical analysis, and we have spared no exertions to ascertain the kinds of crops to which they are best adapted, and the proper methods of cultivating and improving them. And here we would earnestly call the attention of our farmers to the advantages to be derived from a more thorough system of cultivation than is generally practiced. An examination of our soils in different sections of the State has fully confirmed us in the opinion, already expressed to many, of the great benefits that would result from subsoil plowing. We have conversed with many intelligent farmers who have subsoiled their lands, and all agree that the increase of crops by this system has been strongly marked. In most cases the increased profits have been from twenty-five to thirty-five per cent, and in some instances the profits have been more than doubled In districts subject to severe droughts the method here recommended is specially applicable. We could cite examples where, during the present unprecedented dry season, subsoiled lands have yielded from twenty to twenty-five bushels of corn to the acre, while lands adjoining, of precisely the same character, have produced by the superficial method scarcely ten bushels.